Journal of Environmental Management

The public finance response to floods of local governments in Italy

--Manuscript Draft--

Manuscript Number:	JEMA-D-22-05869R1
Article Type:	Research Article
Keywords:	floods; fiscal policy of local governments; Resilience; Vulnerability
Corresponding Author:	Marco Modica, Ph.D School of Advanced Studies L'Aquila, ITALY
First Author:	Marco Modica, Ph.D
Order of Authors:	Marco Modica, Ph.D
	Chiara Lodi
	Giovanni Marin
Abstract:	This paper aims to empirically test the dynamics of budget outcomes of Italian municipalities in the aftermath of floods by accounting for heterogeneous levels of resilience and vulnerability to natural disasters. Our findings are based on a dynamic difference-in-differences model after propensity score matching. They point to substantial impacts in terms of increased capital expenditure and revenues from transfers, which depend on the degree of resilience and vulnerability. Through our analysis, we account for multiple aspects of risk to support policy decisions related to both ex-ante and ex-post disaster occurrence management.
Suggested Reviewers:	Ilan Noy ilan.noy@vuw.ac.nz
	Nicolò Barbieri nicolo.barbieri@unife.it

Title page

The public finance response to floods of local governments in Italy*

Chiara Lodi† Giovanni Marin‡ Marco Modica§

Abstract

This paper aims to empirically test the dynamics of budget outcomes of Italian municipalities in the aftermath of floods by accounting for heterogeneous levels of resilience and vulnerability to natural disasters. Our findings are based on a dynamic difference-in-differences model after propensity score matching. They point to substantial impacts in terms of increased capital expenditure and revenues from transfers, which depend on the degree of resilience and vulnerability. Through our analysis, we account for multiple aspects of risk to support policy decisions related to both ex-ante and ex-post disaster occurrence management.

Keywords: floods, fiscal policy of local governments, resilience, vulnerability

JEL codes: H2, H72, Q54

* We thank Luca Citino, Alessandro Palma, Stefano Clò, Cristiano Antonelli for useful comments and discussions as well as all the participants in presentations of earlier versions of this work at the Workshop "Economics of climate-related extreme events" (2022, Urbino, Italy), Riunione Annuale della Società Italiana di Economia (2022, Torino, Italy), EAERE Conference (2022, Rimini, Italy), ESEE Conference (2022, Pisa, Italy), IAERE Conference (Cagliari, 2022, Italy), GSSI Seminar Series (2022, L'Aquila, Italy), CERCIS Workshop (2021, Ferrara, Italy), SEEDS Annual Workshop (2021, online), ERSA Congress (2021, online). Usual disclaimers apply.

Giovanni Marin and Chiara Lodi acknowledge funding from the PRIN 2017 project 20177J2LS9 004 'Innovation for global challenges in a connected world: the role of local resources and socio-economic conditions'.
† Department of Economics, Society, Politics, University of Urbino Carlo Bo, Department of Economics, Society, Politics; SEEDS, Italy. E-mail: chiara.lodi@uniurb.it. ORCID: 0000-0002-3749-2286

‡ Department of Economics, Society, Politics, University of Urbino Carlo Bo, Department of Economics, Society, Politics; SEEDS, Italy. E-mail: giovanni.marin@uniurb.it. ORCID: 0000-0002-7396-1561

§ Gran Sasso Science Institute, L'Aquila, Italy. E-mail: marco.modica@gssi.it. ORCID: 0000-0002-1759-8665

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

Dear Editor,

I am grateful for the opportunity to revise the paper '*Fiscal policy response of local governments to floods in Italy*', co-authored with Prof. Giovanni Marin and Dr. Chiara Lodi (University of Urbino Carlo Bo, IT) for possible publication in the '**Journal of Environmental Management**'.

The paper has been reviewed according to the suggestions provided by the reviewers. In particular, we add more details on specific technical aspects and we enriched the policy discussion. We also have slightly changed the title as a result of our reasoning on reviewers' comments and it sounds now as: "*The public finance response to floods of local governments in Italy*". Furthermore, as required, we reduced the length of the paper of 10%.

The paper is not being considered for publication elsewhere and it has not already been published elsewhere. We hope you would consider the paper interesting for '**Journal of Environmental Management**'.

If you need further information or clarification, do not hesitate to contact me

Yours Faithfully,
Marco Modica

Via Michele Iacobucci, 2 - 67100 L'Aquila +39 0862 428 433 info@gssi.it www.gssi.it

First of all, we wish to thank the editor and the two anonymous reviewers for reading this work with such care and for their useful suggestions and comments on the manuscript. We have addressed them as detailed below. We kindly thank you for your effort.

Editor

Following this message are the reviews of the above-referenced manuscript. We'll be glad to consider this paper for publication after it's been revised in accordance with the reviewers' comments. The paper also needs editorial revision to improve the English. Please have it edited by a native English speaker prior to re-submission.

Due to space limitations in the printed journal, we are requesting that all authors reduce the length of their papers by at least 10% if possible. If your paper includes large tables or datasets, it is preferred that these be published as supplementary material in Science Direct rather than in print. Further information is provided at the end of this message.

With the revised manuscript, please provide a detailed response to the reviewers' comments, indicating how each comment is addressed in the revised manuscript. If you disagree with any of the reviewers' comments, please address them in a rebuttal.

We thank the editor and the two anonymous reviewers for the useful comments and for giving us the opportunity to revise our paper. We considered all the suggestions made by the reviewers in the revised version of the paper. The paper has been reviewed by a professional proofreading and we reduced the length of the paper from 7634 words to 6759. We also have slightly changed the title as a result of our reasoning on reviewers' comments and it sounds now as: "The public finance response to floods of local governments in Italy". Finally, we also have updated highlights. Detailed responses on reviewers' comments are reported below.

Reviewer #1

There is one suggestion (which may be considered in revision). The author(s) should discuss funding or financing sources to meet additional allocations. A debate between transfers vs. taxation would add more value to the paper.

This is a very important point indeed and we thank reviewer 1 for this valuable comment. we add in the Introduction, results and in the conclusion the following sentences:

"*Italy is also the country with the largest absolute uninsured losses in the European Union (Amadio et al., 2019; Donnini et al., 2020; EEA, 2016). Therefore, quite often, the Italian government has funded reconstruction activities by imposing new taxes (e.g., excise duty on oil in 2009 after the L'Aquila earthquake; CNI, 2016). This is an issue for a country highly affected by several hazards, and it casts a shadow on the will of the Italian government to setup prevention and mitigation strategies*".

[...]

"*This effect suggests that at least part of the additional expenditures borne by local governments was financed by national or other subnational governments. At the same time, it seems that local governments do not significantly change their revenues by*

suspending or postponing the collection of local taxes to support the different economic agents (citizens, workers, companies) affected by flooding. Furthermore, floods do not seem to have a substantial (positive or negative) influence on the local tax base. Therefore, the system seems to be based on central government transfers to meet the necessary additional allocations. This could encourage free riding if local institutions choose not to invest in prevention and mitigation, especially by considering that imposing new taxes on the territories affected would turn into a sort of fiscal punishment that is going to be added into the costs already generated by an event".
[…]
"*On average, Italian municipalities respond to flooding events by fostering public investments; this expenditure growth is partly financed by increased transfers from other levels of government. This result highlights the capability of municipalities to cope with floods and react by boosting post-flood recovery. Moreover, the floods in question do not affect the tax base, and the municipalities do not change local tax rates. A system that is fully funded through taxation represents a sort of "bet with nature" that incentivises bad government behaviour, as taxation is seen as cost-neutral with respect to spending in loss prevention. As a result, governments forego prevention and mitigation activities (Modica et al., 2019a). Still, other ways of funding or financing sources aimed at meeting additional allocations might depend on the peculiar characteristics of the affected individuals and territories*".

As an alternative, the author(s) should also apply a fixed effect panel to establish the robustness of results.

Our results were indeed based on a fixed effect panel estimation. That was not clear enough in the description of the empirical strategy, also due to some issue with formulas that disappeared in the conversion from MS Word to PDF. In the revised version of the paper, we explain our specification more explicitly.

<u>Reviewer #3</u>
The notation of the formula is invisible in pp 7-10, the authors should have checked carefully before the submission.

We are sorry for that: in the conversion from MS Word to PDF there was some problem with formula that we did not notice while approving the submission. Formulas are now shown in the manuscript.

The research methodology by Propensity Score and regression analysis is innovative and informative. Nevertheless, too technical presentation on indicators made it difficult to understand its intuition for fiscal policy with a plausible volume and preparation for municipalities.

We revised the description of the empirical strategy and of the indicators to make it more compact and less technical. The table with detailed descriptions of indicators has been moved to the appendix.

The background information of flooding hazards in Italy is insufficient, especially lack of the historical statistics to support the motivation to establish this analytical mechanism.

According to this relevant comment we add in the introduction section more details on the historical impacts and costs of flooding especially in Italy. In details, we add the following paragraph:
"*Italy is very susceptible to hydrogeological risks due to its geological, morphological and hydrographic characteristics. Moreover, illegal building, overbuilding and urbanisation represent other important drivers of risk. According to ISPRA (2021), almost 94% of Italian municipalities show high hydrogeological risk. Specifically, 7 million people, 13.4% of buildings and 84,000 cultural heritage sites are at flood risk. Moreover, according to the EM-DAT database, since the end of the 1930s, Italy has been one of the most damaged countries in terms of deaths, injured/affected people and damages due to extreme floods (54 disasters are reported). Main extreme events concern the entire Po River Basin; northern Italian regions, such as Emilia Romagna, Tuscany, Veneto, Lombardy and Liguria, are highly affected by floods. In 1951, the area of Polesine, the territory located between the lower course of the Adige and Po rivers up to the Adriatic Sea, had suffered the most dangerous flood of the last century: 239 deaths and around 3 million of damages have been recorded (EM-DAT). Overall, a 2012 study of ANCE/CRESME estimated that 61.5 billion euros of public funds were provided by the Italian government for recovery after hydrogeological events between 1944 and 2012 (about 1 billion euros per year), and the estimated costs are even higher (Zampetti et al., 2012). Italy is also the country with the largest absolute uninsured losses in the European Union (Amadio et al., 2019; Donnini et al., 2020; EEA, 2016).*"

- Dynamics of budget outcomes of Italian municipalities in the aftermath of floods
- Italian municipalities react to floods by increasing capital investments
- Results greatly depend on the degree of resilience and vulnerability of municipalities
- More resilient and less vulnerable municipalities better use available resources
- Less resilient and more vulnerable municipalities highly depend on transfers

The public finance response to floods of local governments in Italy

Abstract

This paper aims to empirically test the dynamics of budget outcomes of Italian municipalities in the aftermath of floods by accounting for heterogeneous levels of resilience and vulnerability to natural disasters. Our findings are based on a dynamic difference-in-differences model after propensity score matching. They point to substantial impacts in terms of increased capital expenditure and revenues from transfers, which depend on the degree of resilience and vulnerability. Through our analysis, we account for multiple aspects of risk to support policy decisions related to both ex-ante and ex-post disaster occurrence management.

Keywords: floods, fiscal policy of local governments, resilience, vulnerability
JEL codes: H2, H72, Q54

1 Introduction

Over the past 50 years, climate-induced disasters have accounted for about 50% of worldwide disasters recorded on the EM-DAT database and over 70% of all economic losses, which have been estimated at about 3.7 trillion dollars (WMO, 2021). Even though scholars still do not have the smoking gun that indicates the role of human activity in the increasing global occurrence of small-scale extreme weather events, a growing number of studies points to a causal link between climate change and such events, especially extreme rainfalls that turn into flooding (WMO, 2021; Kirchmeier-Young and Zhang, 2020).

Today, it is well recognised that climate change (CC) represents one of the most urgent and fundamental problems that public and private actors must face to reduce the number of victims and injured from extreme climate-induced events as well as their associated economic costs. CC is likely to exert a high influence on future extreme natural events, which will damage local areas and communities. However, the amount of damage depends on the combination of the actual occurrence of hazards (probability and magnitude) and the inherent socioeconomic characteristics of the affected areas, which can be proxied with the multifaceted concepts of resilience, vulnerability and exposure (Marin et al., 2021). For this reason, it would be more correct to talk about "socio-natural hazards" instead of "natural disasters" (Hallegatte, 2014a).

The damage arising from an extreme event depends not only on physical factors but also on the ability of local communities to be prepared for, face, mitigate and respond to the event. Furthermore, the occurrence of natural disasters is initially faced by local public institutions that assess the risk and manage first emergency response, as well as search and rescue activities. These capabilities are connected with their level of proactivity; underprepared areas are the most damaged ones (Breckner et al., 2016; Chan et al., 2016; Kahn, 2005; Ostadtaghizadeh et al., 2016; Parsons et al., 2016; Raschky, 2008). Differences in the shock adaptation capacity may also vary according to spatial and geographical characteristics, such as an area's degree of rurality.[1] Therefore, even though national and supranational entities are in charge of urgent actions to cope with CC impacts, local governments should rethink their climate risk assessment framework. This framework should deal with mitigation and adaptation activities aimed at preventing the effects that a changed climate might have on local territories from an ex-ante perspective and helping post-disaster recovery from an ex-post perspective.

[1] As highlighted by Cutter et al. (2016), economic capital is more relevant to increasing the disaster resilience of urban areas, while social capital is more important in enhancing the resilience of rural areas.

However, most of the mitigation and adaptation activities are also related to healthy local public finance conditions and even though the literature has highlighted the impact of extreme climate events on public finance (e.g., Heipertz and Nickel, 2008; Lis and Nickel, 2010; Phaup and Kirschner, 2010), few studies have analysed the effect of selected impacts on government budgets (e.g., Bachner and Bednar-Friedl, 2019). Little attention has been paid to the shocks generated by extreme climate events in terms of local public financing capabilities and fiscal policies. We argue that the areas that are more susceptible to suffering from a changed climate will necessarily drain resources from the local public budget to prevent and mitigate risks and recover after a shock affects them. This might be detrimental in the case of "recurrent" disasters, such as floods. Over the past decades, due to global warming, floods have captured higher attention as their frequency, severity and intensity are constantly rising worldwide (EEA, 2010; IPCC, 2022). This hazard has underlined how major urban centres that have not implemented an adequate risk assessment framework are the most damaged areas (Benson and Clay, 2004). The EEA has estimated about 446 billion euros of economic losses caused by climate-related extreme events between 1980 and 2019.

Given these premises, our work aims to empirically test the dynamics of local governments' budgetary outcomes in the aftermath of floods in a country that is highly vulnerable to such events – Italy (Faiella and Natoli, 2018). Italy is very susceptible to hydrogeological risks due to its geological, morphological and hydrographic characteristics. Moreover, illegal building, overbuilding and urbanisation represent other important drivers of risk. According to ISPRA (2021), almost 94% of Italian municipalities show high hydrogeological risk. Specifically, 7 million people, 13.4% of buildings and 84,000 cultural heritage sites are at flood risk. Moreover, according to the EM-DAT database, since the end of the 1930s, Italy has been one of the most damaged countries in terms of deaths, injured/affected people and damages due to extreme floods (54 disasters are reported). Main extreme events concern the entire Po River Basin; northern Italian regions, such as Emilia Romagna, Tuscany, Veneto, Lombardy and Liguria, are highly affected by floods. In 1951, the area of Polesine, the territory located between the lower course of the Adige and Po rivers up to the Adriatic Sea, had suffered the most dangerous flood of the last century: 239 deaths and around 3 million of damages have been recorded (EM-DAT). Overall, a 2012 study of ANCE/CRESME estimated that 61.5 billion euros of public funds were provided by the Italian government for recovery after hydrogeological events between 1944 and 2012 (about 1 billion euros per year), and the estimated costs are even higher (Zampetti et al., 2012). Italy is also the country with the largest absolute uninsured losses in the European Union (Amadio et al., 2019; Donnini et al., 2020; EEA, 2016). Therefore, quite often, the Italian government has funded reconstruction activities by imposing new taxes (e.g., excise duty on oil in 2009 after the L'Aquila earthquake; CNI, 2016). This is an issue for a country highly affected by several hazards, and it casts a shadow on the will of the Italian government to setup prevention and mitigation strategies. Therefore, we consider different levels of socioeconomic resilience and vulnerability among Italian municipalities to infer whether their capacity to cope with disasters is affected by their socioeconomic characteristics. Understanding a municipality's fiscal response to disasters is fundamental given that some previous decisions about the allocation of financial resources and taxation can be changed (Benson and Clay, 2004; Tulbee, 2019; Miao et al., 2020). On the expenditures side, planned investments and ongoing projects might be postponed or abandoned, while new projects and expenditures might be needed to cope with emergencies and post-event reconstruction. On the revenues side, local taxation provisions are generally subject to negative (tax cuts for post-event recovery or reduced tax base) or positive (additional transfers and taxation to cope with new expenditures) changes (Benson and Clay, 2004).

Currently, there are few studies on the impact of extreme climate events on the financial and budgetary outcomes of public institutions, especially at the subnational level (Faiella and Natoli, 2018). The literature focuses on analysing the consequences of extreme hazards on fiscal policies at the country level, with mixed results (Heirpertz and Nickel, 2008; Lis and Nickel, 2010; Noy and Nualsri, 2011; Melecky and Raddatz, 2014; Miao et al., 2018). The findings of this literature depend on the different aspects that are considered (e.g., event severity, country and government characteristics, model assumptions and variables). For example, Noy and Nualsri (2011) used a sample of 42 developed and developing countries in the 1990–2005 period. In the case of developed countries, they found that natural disasters have a negative effect on revenues and cash surplus; they also recorded an increase in government payments and outstanding debt. In the case of developing countries, all fiscal variables are negatively affected by extreme events, except cash surplus. Similarly, Lis and Nickel (2010) and Melecky and Raddatz (2014) found that less advanced nations face a larger effect on public nominal budget balances in the aftermath of extreme events compared to advanced economies.

However, few studies have analysed the fiscal response in the aftermath of extreme climate events at the subnational level. Miao et al. (2020) estimated the dynamic effects of several natural disasters on government finance in 30 Chinese provinces in the period 1994–2014. Their results suggest that expenditures and intergovernmental transfers increase in the aftermath of the event and then gradually decrease over time, while a limited effect on revenues was found. Jerch et al. (2021) and Tulbee (2019) analysed the relationship between natural disasters and local (municipal/county) government finances in the United States. Jerch et al. (2021) found that hurricane exposure causes a decline in revenues and expenditures in the long run as a result of the fall in local tax revenues. In the short run, the decrease in revenues is mitigated by incoming intergovernmental transfers. Tulbee (2019) examined the impact of extreme climate events (as declared by the Federal Emergency Management Agency) on the fiscal spending and revenues of counties in the state of Kentucky between 2007 to 2017. He found a significant increase in intergovernmental transfers and a decrease in incoming taxes, while no significant change in expenditures per capita.

Considering the existing literature, we constrain our analysis to floods affecting municipalities in nine Italian NUTS2 regions in the 2013–2016 period. To estimate the impact of floods, we have implemented a dynamic difference-in-differences approach coupled with propensity score matching over a panel of 4,185 Italian municipalities with monthly data. Since the amount of loss and the ability to react to extreme climate events also depend on the structural characteristics of each municipality, we have investigated the effects of selected floods on budgetary outcomes by distinguishing between municipalities with high and low resilience and vulnerability. To the best of our knowledge, our work is the first to assess the impact of floods on budget outcomes at the municipal level by also analysing conditions of vulnerability and resilience.

Our results suggest that on average, Italian municipalities react to floods by increasing investments. This effect is not counterbalanced by adjustments in revenues, so substantial imbalances could emerge. Through a deeper analysis of municipal budget breakdowns, we argue that the results greatly depend on the municipalities' degree of resilience and vulnerability. Specifically, we show that more resilient (and less vulnerable) municipalities are better able to face floods because they can handle greater flows of already available resources without waiting for transfers from other government levels.

2 The general framework for disaster management in Italy

In this article, we focus on a specific policy implemented by the Italian government; that is, the decision by the Italian Council of Ministers on 28 July 2016 to allocate funds for reconstruction interventions linked to 49 flooding events that had national relevance and affected the country's regions over the 2013–2016 period. For all these events, a state of emergency was declared.

According to Italian legislation, a state of emergency can be declared after the occurrence or in the imminence of exceptional events, such as extreme natural events (earthquakes, floods, drought and, more recently, the Covid-19 pandemic). This state is strictly regulated by the law and declared by the Council of Ministers in agreement with the governors of the affected regions. The state of emergency allows public authorities to act urgently and with extraordinary powers (i.e., derogating from ordinary legislation). This state lasts one year and can be extended only for an additional 12 months. According to the Italian Civil Protection Department, a state of emergency has been declared in Italy more than 100 times since 2013.

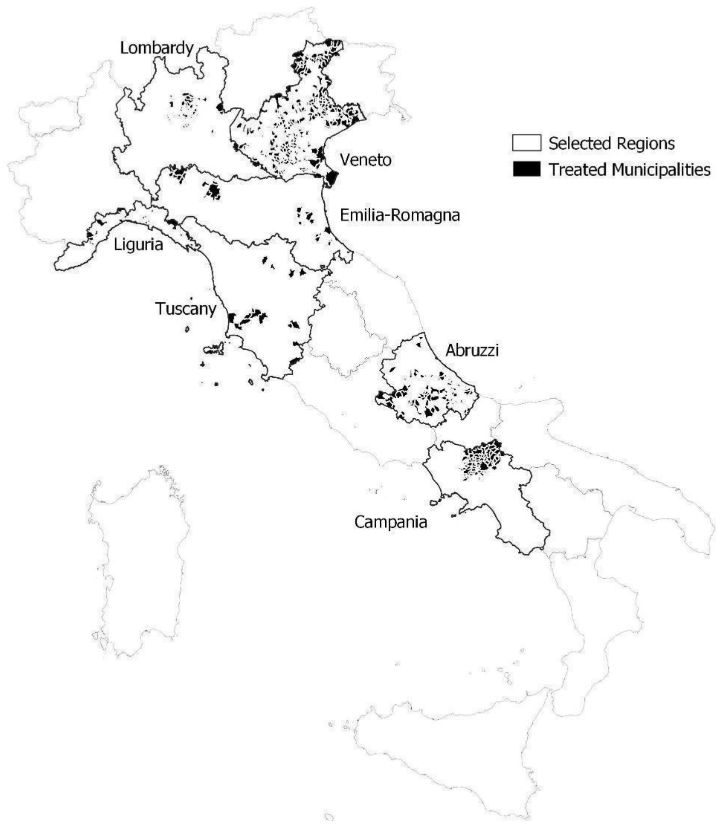
The decision of the Council of Ministers allows for the compensation of costs suffered by private citizens and economic actors (e.g., repairing private buildings and businesses' structures, systems and equipment), as well as for the purchase of stocks of raw materials, semi-finished and finished products that were damaged or destroyed due to the event.

The first set of activities is carried out by the head of the Civil Protection; a regional delegate is then appointed when the emergency phase has ended. The Civil Protection system generally differentiates its activities by type of event and type of operative centre according to the geographical extent of the event. Overall, a hierarchical structure from the municipal to the national level is put in place, with the local mayor acting as the authority responsible for the initial activities of the Civil Protection.

We analysed the Civil Protection and Delegate Commissioner ordinances providing reconstruction funds in a selection of 40 flooding events, and we considered all the municipalities that have received funds.[2] In our empirical analysis, we consider a municipality as treated whenever it receives reconstruction funds. For instance, for the events affecting the Campania region in 2015, we have recognised 152 treated municipalities out of 647. Our starting sample includes 4,185 municipalities from nine Italian regions: Abruzzo, Basilicata, Campania, Emilia Romagna, Liguria, Lombardy, Sardinia, Tuscany and Veneto. In this sample, 517 municipalities are classified as treated; their geographical distribution is shown in Figure 1.

[2] As mentioned at the beginning of section 2, the document of the Italian Council of Ministers identified 49 flooding events, but for nine of them, the estimation of damages is not completed.

Figure 1. Selected Regions and Treated Municipalities



Note: Sardinia and Basilicata are not shown on the map due to the absence of treated municipalities.

3 Empirical strategy

We aim to estimate the effect of floods on municipalities' budgets by means of a dynamic difference-in-differences approach. Even though we do not expect a risk of reverse causality between floods and local governments' budget outcomes, the likelihood that a flood occurs in a specific municipality generating damages that justify the declaration of a state of emergency might be correlated with some attributes that also influence the dynamics of our outcome variables. For example, high-hazard local governments could increase their investments in the maintenance of water-related infrastructure (e.g., reinforcement of levees) before the usual flooding months. Furthermore, the patterns of revenues and/or expenditures of more resilient municipalities are more (or less) smooth than the ones of less resilient ones. For this reason, we decided to identify a priori a proper counterfactual by matching treated municipalities to non-treated ones based on observable characteristics. Specifically, we estimate the propensity score as the predicted probability of being subject to a flood given the pre-treatment observable features of the municipalities and then match each treated municipality with one (or more) non-treated municipality that has the closest probability of being treated. We then run a dynamic difference-in-differences model on the matched sample.

We exploit the high frequency (monthly) of our data on municipalities' revenues and expenditures to identify the short-term dynamics of the outcome variables in the aftermath of a flood. To limit the issue of seasonality, we group time periods in semesters. Instead of identifying ex-ante an arbitrary month as the beginning of the semesters (e.g., January and July), for each event, we consider the first post-treatment semester to begin in the month when the flood occurred.[3]

The difference-in-differences model is expressed by the following equation:

$$y_{it} = \alpha_i + \tau_t + \gamma_{jt} + \eta_{t-2} Treated_i + \sum_{s=0}^{3} \beta_{s+t} \, Treated_i + \varepsilon_{it} \quad (1)$$

where y_{it} is the outcome variable for municipality *i*, in the *t* semester; α_i is the municipality fixed effect that accounts (in a flexible way) for all time-invariant characteristics that could be correlated with both the outcome variables and the treatment; τ_t is the semester fixed effect; γ_{jt} is the calendar month dummy for month *j*, which is allowed to exert a time-varying effect on the outcome variable to account for seasonality. The variable $Treated_i$ is the dummy variable that equals 1 for treated municipalities (as defined in section 3) and 0 for untreated matched municipalities. We assume that the occurrence of a flood in municipality *i* in a specific month is exogenous (conditional on matching). The two sets of parameters of interest are η_{t-2} and β_{s+t}, which measure, respectively, pre-trends and the average effect for treated municipalities (ATT) on municipalities' budgetary outcomes. The reference semester is the one prior to the event semester. Finally, ε_{it} represents the IID error term.

4 Disaster risk assessment and propensity score matching

Concerning the estimation of the propensity score, the choice of the independent variables is connected with the concept of disaster risk. The risk of a specific climate-related disaster

[3] We consider semesters instead of months to account for the seasonality of local governments' expenditures and, especially, revenues. In Italy, local governments collect or receive the bulk of their revenues in December and June (i.e., exactly six months apart). The definition of the beginning of the semester is specific to each treated municipality, depending on when the flood occurs. As for the non-treated (matched) municipalities, we align their time index to the one of the municipalities to which they are matched. For example, imagine that municipality A is subject to a flood in October 2014. Then, according to our propensity score matching procedure, municipalities B and C are matched to municipality A. The time index *t* for the three municipalities will be set to 0 for the semester October 2014–April 2015 (i.e., the "event semester"). This is a particular application of a staggered difference-in-differences approach that accounts for the recent criticism by Baker et al. (2022).

represents the probability of value losses in terms of different aspects, such as damages to economic activity and the well-being of affected areas. The risk is thus a function of the vulnerability, resilience, exposure and hazard of the municipality under analysis (Hallegatte, 2014b; Marin et al., 2021). More formally, the risk for municipality *i* can be defined as:

$$R_i = f(V_i, Res_i, E_i, H_i) = V_i * (1 - Res_i) * E_i * H_i \qquad (2)$$

where V_i corresponds to the vulnerability of municipality *i*; Res_i is its resilience; E_i represents its exposure, and H_i the flood-specific hazard. If a municipality reaches a high resilience and/or a low vulnerability, mitigation of risks occurs even in presence of high hazard probability and exposure, so the local system is expected to be weakly affected by a flood. Conversely, the risk is likely to be high when the municipality shows low resilience and/or high vulnerability. A detailed explanation of how the indicators are built is found below.

Vulnerability is defined as the set of characteristics of a municipality that can potentially generate harm, independently of the flood risk (Sarewitz et al., 2003). By adopting the same approach as Modica et al. (2019b) and Marin et al. (2021), a composite vulnerability index was built that considers 17 municipality features. Each feature was weighted with the number of times it was used in the literature to measure vulnerability. Each variable was normalised to range between 0 and 1; then, the composite indicator was further normalised to range between 0 (low vulnerability) and 1 (high vulnerability).[4] To consider only relevant (discrete) differences across municipalities, we defined a dummy variable equalling 1 when the municipality has a vulnerability higher than its median value and 0 when this is not the case.

Resilience is the ability of a system to resist, recover, renew and realign after disturbances or shocks (Pimm, 1984; Rose, 2005; Martin, 2012; Zhou and Chen, 2020). As was the case for vulnerability, resilience was measured by starting from a composite index following Modica et al. (2019) and Marin et al. (2021), which accounts for 13 socioeconomic variables.[5] Aggregation, weighting and normalisation followed the same procedure used for vulnerability, leading to an indicator of resilience ranging from 0 (low resilience) to 1 (high resilience). As for vulnerability, we defined a dummy variable equalling 1 when the resilience of the municipality is higher than its median value and 0 when this is not the case. Please note that vulnerability and resilience have two different meanings and that their theoretical relation is

[4] For a complete description of the socioeconomic variables of the vulnerability index, see Table A.2 in Appendix A.

[5] For a complete description of the socioeconomic variables of the resilience index, see Table A.3 in Appendix A.

not univocal; rather, it depends on the framework one adopts (see Cutter et al. 2008 for details). Without entering into this debate, our research framework considers the two concepts as different though interrelated; this gives rise to distinct but quite strongly correlated indicators.

Exposure can be defined as all the assets and the population that may be affected by a hazard (Hallegatte, 2014b). It includes socioeconomic and geophysical features of municipalities. A municipality's exposure was quantified by collecting socioeconomic and geographical data from different sources. From the socioeconomic perspective, population numbers and households' taxable income were considered based on ISTAT and Ministry of Economy and Finance data, respectively.[6] We also took into account the following geographical characteristics of the municipalities: altitude (metres above sea level), coastal/island classification (proximity to the sea or surrounded by the sea) and area (measured in square kilometres).

Hazard is the probability of occurrence of an extreme event that can create perturbations to the economic system. In our study, the hazard refers to floods. The flood probability for each municipality was measured as the share of the total area at risk of flooding (hydrological risk). ISPRA has identified three degrees of hydrological risk: high probability, with a return period of 20–50 years (frequent floods); medium probability, with a return period of 100–200 years (less frequent floods); and low probability of floods or other extreme events (ISPRA, 2021). The hazard measure ranges between 0 and 1 according to the area that lies in each of the three groups, and a weighted average was calculated and also normalised between 0 and 1 to get a comprehensive flood hazard variable for the municipality. In our estimation of the propensity score, the municipality risk variables (vulnerability, resilience, exposure and hazard) are considered to be time-invariant.[7]

To account for possible differences in the pre-trends of the outcome variables between treated municipalities and controls, we estimate a separate propensity score for each dependent variable, including as a covariate the six-month change in (log) outcome prior to treatment. Finally, as we also want to provide evidence about the heterogeneous effect for municipalities with different levels of resilience and vulnerability, we also interact these pre-trends with our dummies for resilience and vulnerability. To be as flexible as possible in the identification of

[6] Concerning households' taxable income, the database of the Ministry of Economy and Finance provides information on the sum of incomes declared by residents of the municipality that is subject to the general income tax for individuals (IRPEF). In our estimation of the propensity score, we included the lagged value of this income.

[7] In contrast, income and population are time-varying variables. However, given that we only have information on yearly change and the high persistence of these variables, we included them in our propensity score with a 1 year.

good matches, we estimate each probit separately for each month when at least one event occurred.[8]

Table 1. Propensity Score Matching Variables Description

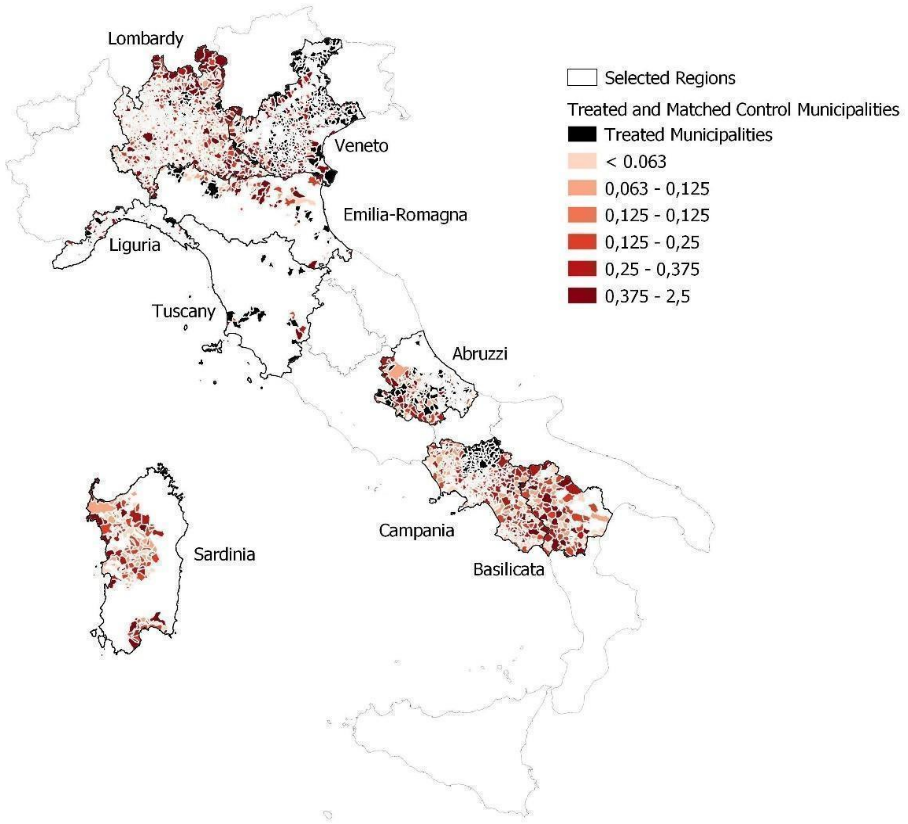
Variable	Description
Population	Annual resident municipal population on 1st January.
Income	Lagged per capita general income tax IRPEF.
Land Area	Area of a municipality expressed in square kilometres.
Altitude	Metres over sea level of the municipality's city hall.
Island	Dummy equals 1 if part of the territorial area of the municipality overlooks the sea, 0 otherwise.
Coastal	Dummy equals 1 if the municipality area is surrounded by the sea, 0 otherwise.
Resilience	Dummy equals 1 if the resilience of the municipality is above or equal to the third quartile, 0 otherwise.
Vulnerability	Dummy equals 1 if the vulnerability of the municipality is above or equal to the third quartile, 0 otherwise.
Hazard	Share of the total area (in squares kilometres) at hydrogeological risk.

We match each treated municipality to the two nearest neighbours in terms of predicted propensity score and impose a *caliper* to limit the bias arising from bad matching.[9] Exact matching between treated and controls in terms of resilience and vulnerability is imposed.[10]
To test the validity of the matching based on the propensity score, we test whether treated and controls share the same average characteristics by means of a simple t-test. We contrast these mean comparisons with a mean comparison between treated municipalities and all (matched and unmatched) untreated municipalities to understand whether the matching improves homogeneity in the two groups of treated and controls. Our results are reported in Appendix B, Tables B.1.1 and B.1.2. They suggest that the matching substantially reduces the bias that could arise if municipalities with systematically different characteristics had systematically different trends in the outcome variables. All the observable characteristics show no statistical difference, on average, between treated and matched municipalities at conventional levels of statistical significance after matching on the propensity score. Instead, if we consider all the untreated municipalities as control groups, the differences were generally significantly different from zero (see Table B.1.1).

[8] February 2014, March 2014, September 2014, October 2014, November 2014, February 2015, March 2015, September 2015 and October 2015. The results based on a single propensity score for all the events are very similar to the ones reported in the article and are available upon request.
[9] We apply the usual rule of thumb to set the caliper to 1/4 of the standard deviation of the predicted propensity score.
[10] As an additional robustness check, we add one additional dimension to the exact matching; that is, the quartile of the outcome's six-month pre-trend. The results are reported in Appendix C.

Figure 2 maps treated and matched control municipalities. There are 517[11] treated municipalities and, based on propensity score matching, 2,117 matched control municipalities (for at least one outcome variable).

Figure 2. Treated and Matched Control Municipalities



Note: Treated municipalities are filled in black. Matched control municipalities are filled with different shades of red to account for the average contribution (weight) of each municipality to the building of the counterfactual across all different events and outcome variables.

5 Results

5.1 Baseline results

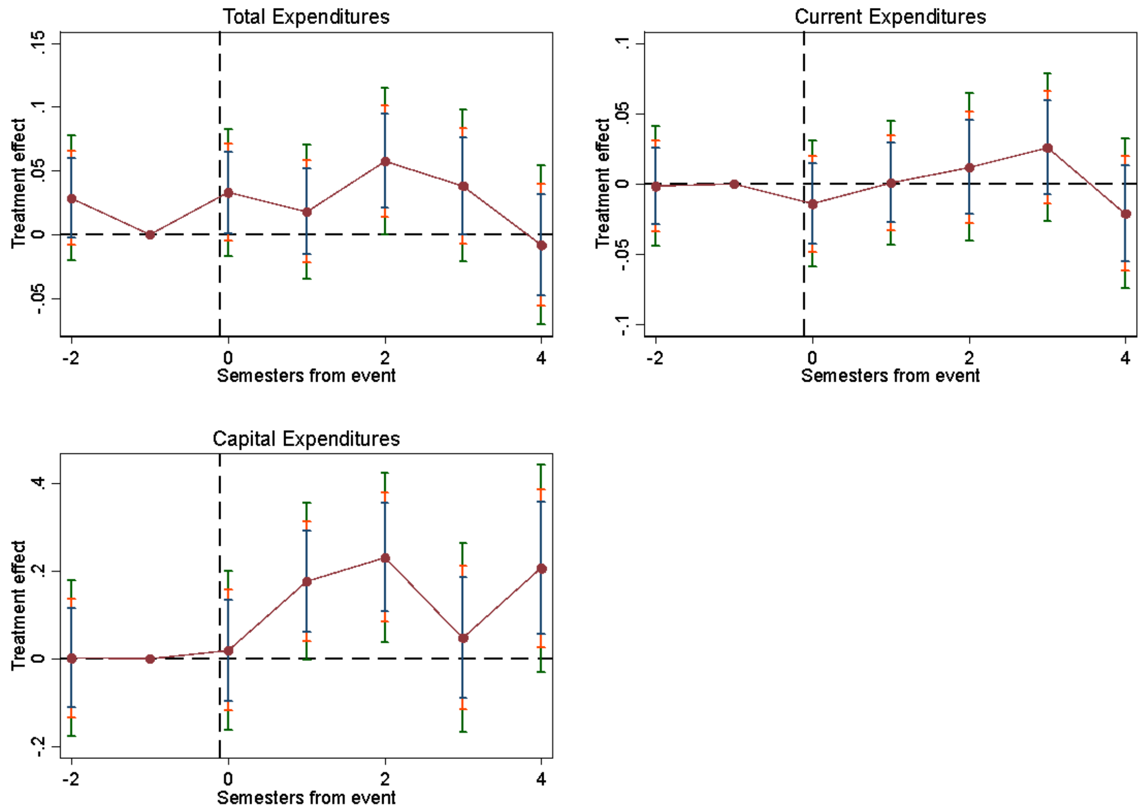
The dynamics of our estimated average treatment effect of floods on municipalities' budgetary outcomes are reported in Figures 3 (expenditures) and 4 (revenues). Generally speaking, no significant pre-trend exists, so any post-treatment deviation of the trends between treated municipalities and the counterfactual could be ascribed to the extreme event.

In all the figures, when "semesters from event" equals 0 (t = 0), we are referring to the "event semester." The treatment effect on total expenditures is positive until the third semester after a

[11] Specifically, the whole sample of treated municipalities has 785 observations. Despite this, we only account for 517 because their pre- and post-trends can be fully observed in our reference period (2013–2016). In this way, we avoid the risk of including in the pool of non-treated municipalities those that were affected by flooding prior to 2013 or after 2016, for which we do not have information.

flood; it reverts to zero in the fourth semester. In terms of magnitude, the effect is sizeable: from +3.4% in the event semester to +6% in the third post-treatment semester. Regarding the precision of the estimates, the effects are statistically different from zero in the event semester (p-value < 0.1) and the second (p-value < 0.01) and third (p-value < 0.1) semesters. These results indicate that local governments react to flooding quite soon by increasing expenditures, even though the full potential is reached one year after the flood. However, it seems that this effect tends to fade away quite rapidly.

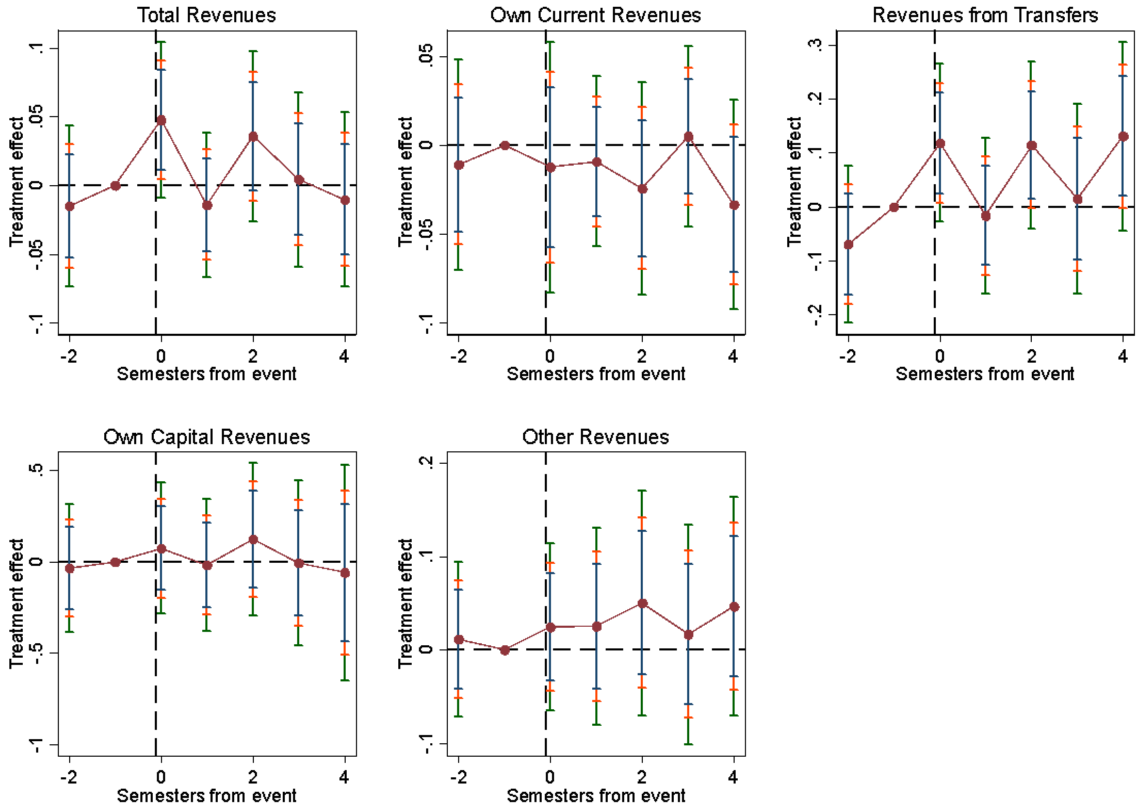
Figure 3. Difference-in-differences Baseline Estimations: Expenditures



Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

To dig deeper into the drivers of this overall effect, we consider expenditures in fixed capital (i.e., investments) and current expenditures separately. Public investments represent a large part of expenditures aimed at boosting the recovery and reconstruction of infrastructure and buildings that were directly hit by the flood. The effect of a flood on capital expenditures (bottom-left panel of Figure 3) only shows up in the second semester after the flood (t = 1) and further grows in the third semester (t = 2). This effect is statistically different from zero (p-value < 0.1) and quite large in magnitude; it corresponds to an increase (compared to the counterfactual) of 19% in the second semester and 26% in the third semester. Considering current expenditures (e.g., personnel expenditures), we find no significant effect on treated municipalities in the aftermath of a flood; this might signal that climate disasters provoke immediate impacts on municipal capital and physical assets, which wear off when these assets are replaced.

Figure 4. Difference-in-differences Baseline Estimation: Revenues



Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

When focusing on revenues (Figure 4), we observe that the effect of floods on total revenues is characterised by a non-monotonic trend. An instantaneous (t = 0) significant increase in total revenues happens when the shock occurs, which corresponds to a +4.9% increase (significant at 5%). This effect is immediately reabsorbed in t = 1. In the third semester (t = 2), revenues are subject to a new increase (not statistically significant) and then start to steadily decline.

By adopting the same approach as with expenditures, we break down total revenue into its main components. Interestingly, no significant effects are found for current, capital and other revenues. However, when considering revenues from transfers, we estimate a positive and significant impact in the event semester and the third semester. This effect suggests that at least part of the additional expenditures borne by local governments was financed by national or other subnational governments. At the same time, it seems that local governments do not significantly change their revenues by suspending or postponing the collection of local taxes to support the different economic agents (citizens, workers, companies) affected by flooding. Furthermore, floods do not seem to have a substantial (positive or negative) influence on the local tax base. Therefore, the system seems to be based on central government transfers to meet the necessary additional allocations. This could encourage free riding if local institutions choose not to invest in prevention and mitigation, especially by considering that imposing new taxes on the territories affected would turn into a sort of fiscal punishment that is going to be added into the costs already generated by an event. To summarise, in Italy, flooded municipalities tend to respond by boosting the level of public investment (with a six-month delay), which is financed (at least partly) by increased transfers from other levels of government. This result suggests a good capacity to cope with extreme events and act with the aim of enhancing post-flood recovery. In contrast, no change is observed in terms of current expenditures and other revenues, which means that the events in question did not substantially erode the tax base and that local governments did not change local tax rates.

5.2 Heterogeneous effects: high- vs low-resilience municipalities

Since municipalities react differently to extreme climate events depending on their characteristics, we provide evidence about the effect's heterogeneity based on the level of resilience and vulnerability. Most studies of economic resilience and vulnerability support the notion that a system's ability to react to and cope with shocks varies according to its characteristics. However, to our knowledge, few studies have shown the actual mechanism through which a resilient system is better able to cope with unexpected shocks. In our work, we show how the ex-ante more resilient and less vulnerable municipalities are able to cope with unforeseen events through their capacity to better use internal budgetary resources, while less resilient and more vulnerable municipalities mostly depend on transfers. Overall, our work may be considered an explicit test of the capacity of resilient municipalities to cope with unpredicted shocks and the ensuing socioeconomic vulnerability.

We consider the median value of resilience and vulnerability as the threshold to identify high- vs low-resilience/vulnerability municipalities. As shown in Table 2, 35.20% of treated municipalities are highly resilient and less vulnerable to floods. Less resilient and more vulnerable damaged municipalities are similarly represented in the sample (38.88%). The residual 26% is distributed between less resilient/less vulnerable (14.12%) and highly resilient/highly vulnerable (11.80%) treated municipalities.

Table 2. Treated Municipalities by Vulnerability and Resilience Level

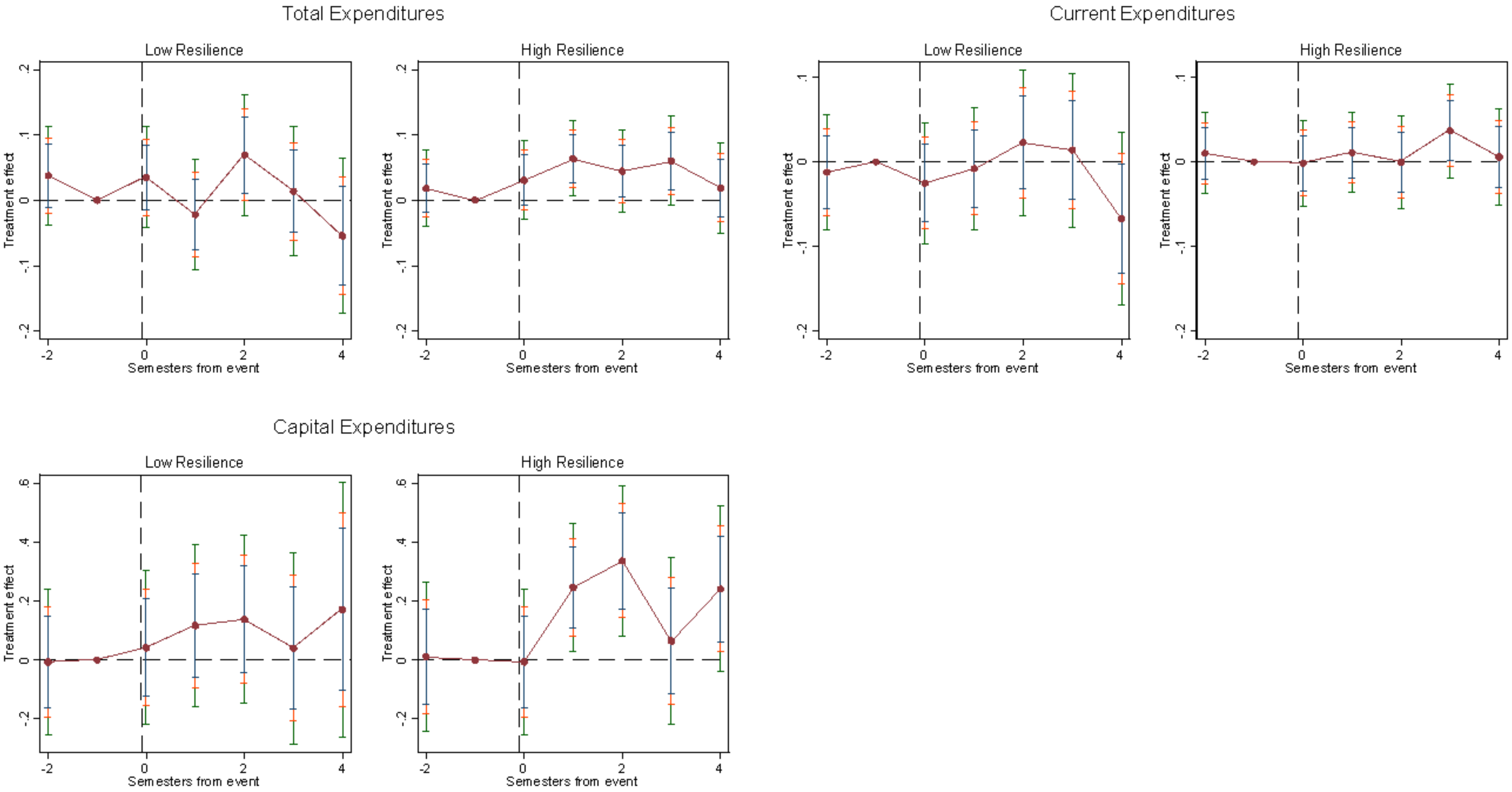
Resilience/Vulnerability	Low	High	Total
Low	**73** 14.12%	**201** 38.88%	**274** 53%
High	**182** 35.20%	**61** 11.80%	**243** 47%
Total	**255** 49.32%	**262** 50.68%	**517** 100%

First, we break down our sample by resilience; the results are reported in Figures 5 (expenditures) and 6 (revenues). In general, less resilient municipalities hit by floods do not change their pattern of (total, current and capital) expenditures; the effects are not statistically different from zero, with the sole exception of the increase in total expenditures in the second semester after the event semester (p-value < 0.05). In contrast, we find large and significant effects for resilient municipalities, especially for capital expenditures and total expenditures; we also estimate a positive and significant effect on current expenditures in the third post-treatment semester. In summary, municipalities with high resilience respond quite promptly to flooding by boosting spending in infrastructures and other capital expenditures to favour post-disaster recovery. Moreover, these municipalities also boost current expenditures in the long run. The response to floods of less resilient municipalities is much weaker. This is one of the first pieces of evidence that shows the mechanism through which more resilient municipalities are better able to face extreme events thanks to their higher capacity to handle greater flows of (internal) resources, without waiting for external aid. This highlights two important findings of this work: 1) more resilient subjects have a higher capacity to quickly spend money, thereby immediately starting the recovery process; 2) more resilient subjects are more aware that investments are important to facilitate post-disaster recovery.

The results for revenues, broken down by level of resilience and revenue type (Figure 6), indicate that less resilient treated municipalities record a statistically significant (p-value < 0.1) and substantial increase in total revenues in the semester of the flood with respect to the corresponding counterfactual, which is mostly driven by a substantial increase in transfers from higher or equal levels of government. This does not happen to more resilient municipalities, for which we find no immediate rise in total revenues and a smaller (and not significantly different from zero) increase in transfers compared to less resilient ones, while some evidence of a significant increase in transfers appears in the last observed semester.[12]

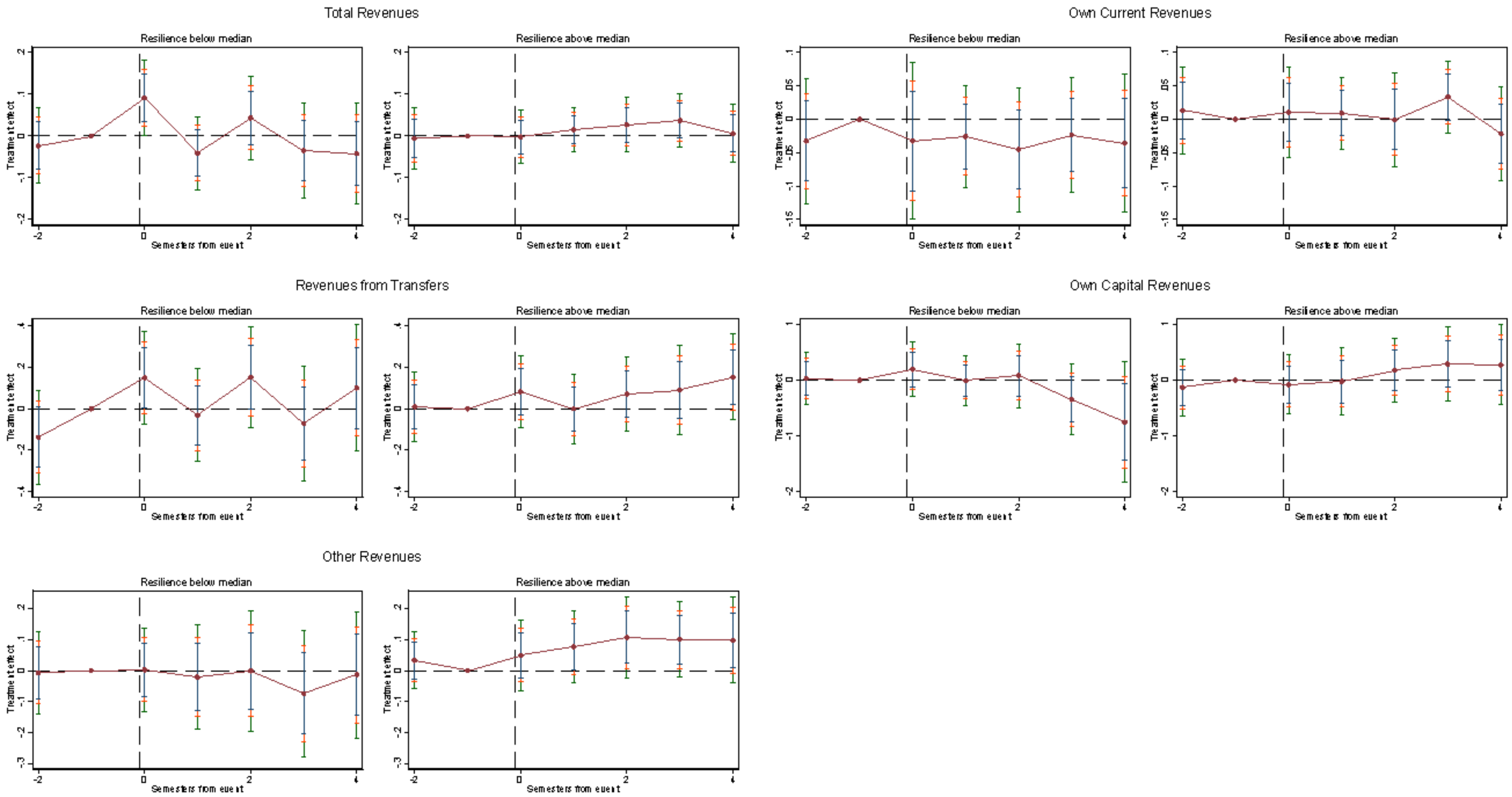
[12] "Other revenues," which are mainly connected to revenues from services provided on behalf of third parties, appear to be positively affected by a flood in highly resilient municipalities.

Figure 5. Difference-in-differences Estimations by Resilience Level: Expenditures



Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

Figure 6. Difference-in-differences Estimations by Resilience Level: Revenues



Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

Our results suggest that other national or subnational governments (e.g., NUTS2 regions) immediately transfer funds to support less resilient municipalities and that these transfers are not effectively used by local authorities with poor resilience. At the same time, highly resilient municipalities promptly respond to a flood by boosting capital expenditures, even without any significant transfer of resources from other levels of government.

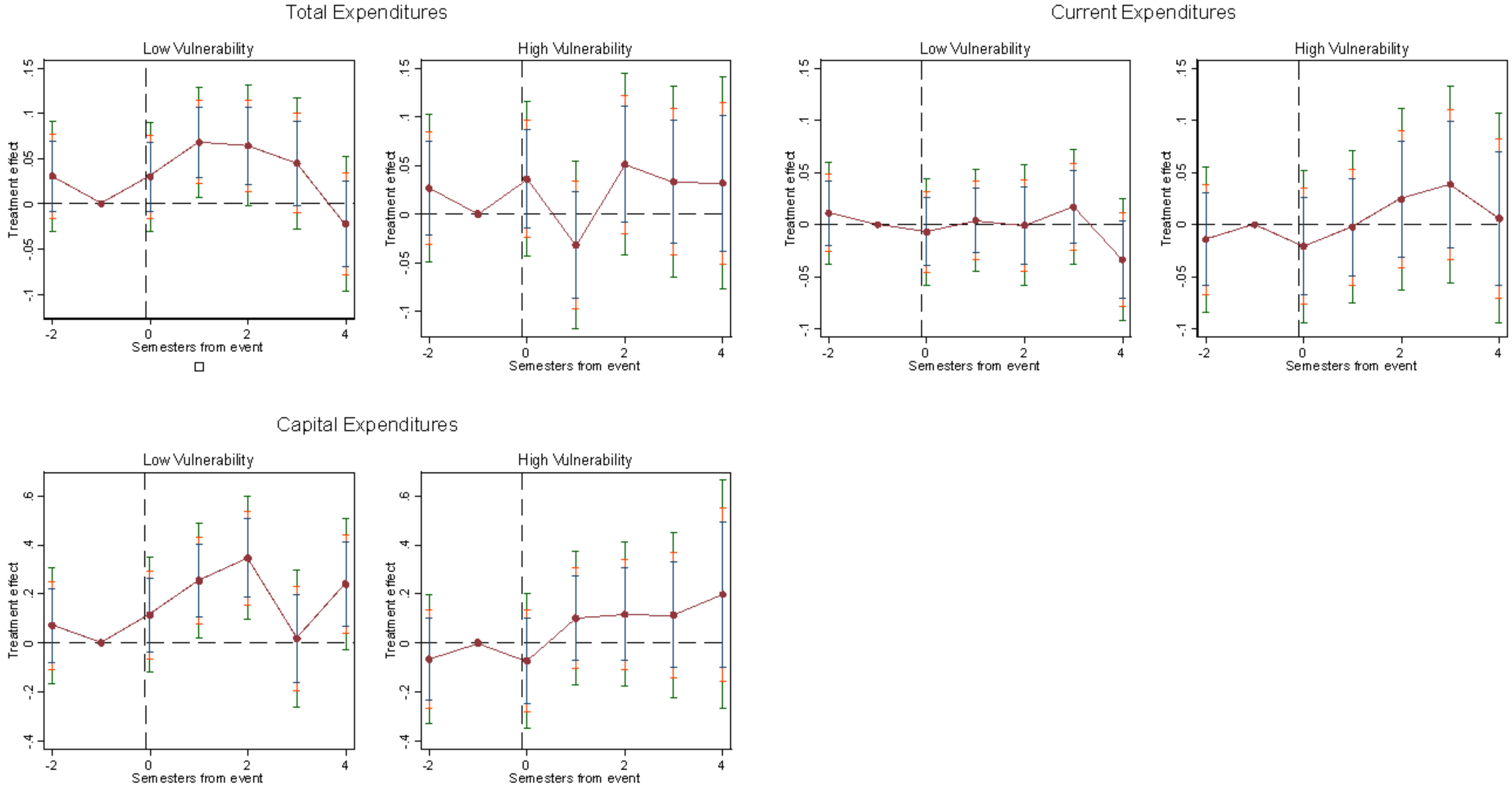
5.3 Heterogeneous effects: high- vs low-vulnerability municipalities

To corroborate our results on resilience, we replicate our analysis by looking at the vulnerability of municipalities. As mentioned before, resilience and vulnerability are strongly negatively correlated (correlation coefficient of -0.77). From our perspective, resilience and vulnerability share some common characteristics but are two separate concepts that capture socioeconomic differences among municipalities. This is reflected in the composition of the two indicators of resilience and vulnerability. Roughly speaking, we suggest that resilience is the capacity of a municipality to prevent damages from becoming embedded in the economic system through a slowing down of economic growth, while vulnerability is related to the capacity to suffer socioeconomic losses.

Figure 7 shows the differential effects broken down by the level of vulnerability for expenditures. As expected, these results mirror those broken down by resilience (Figures 5 and 6). We estimate a substantial increase in total expenditures, driven by capital expenditures, in the aftermath of a flood (compared to the counterfactual) for municipalities with a low level of vulnerability. No significant effect is found for current expenditures nor for high- or low-vulnerability municipalities.

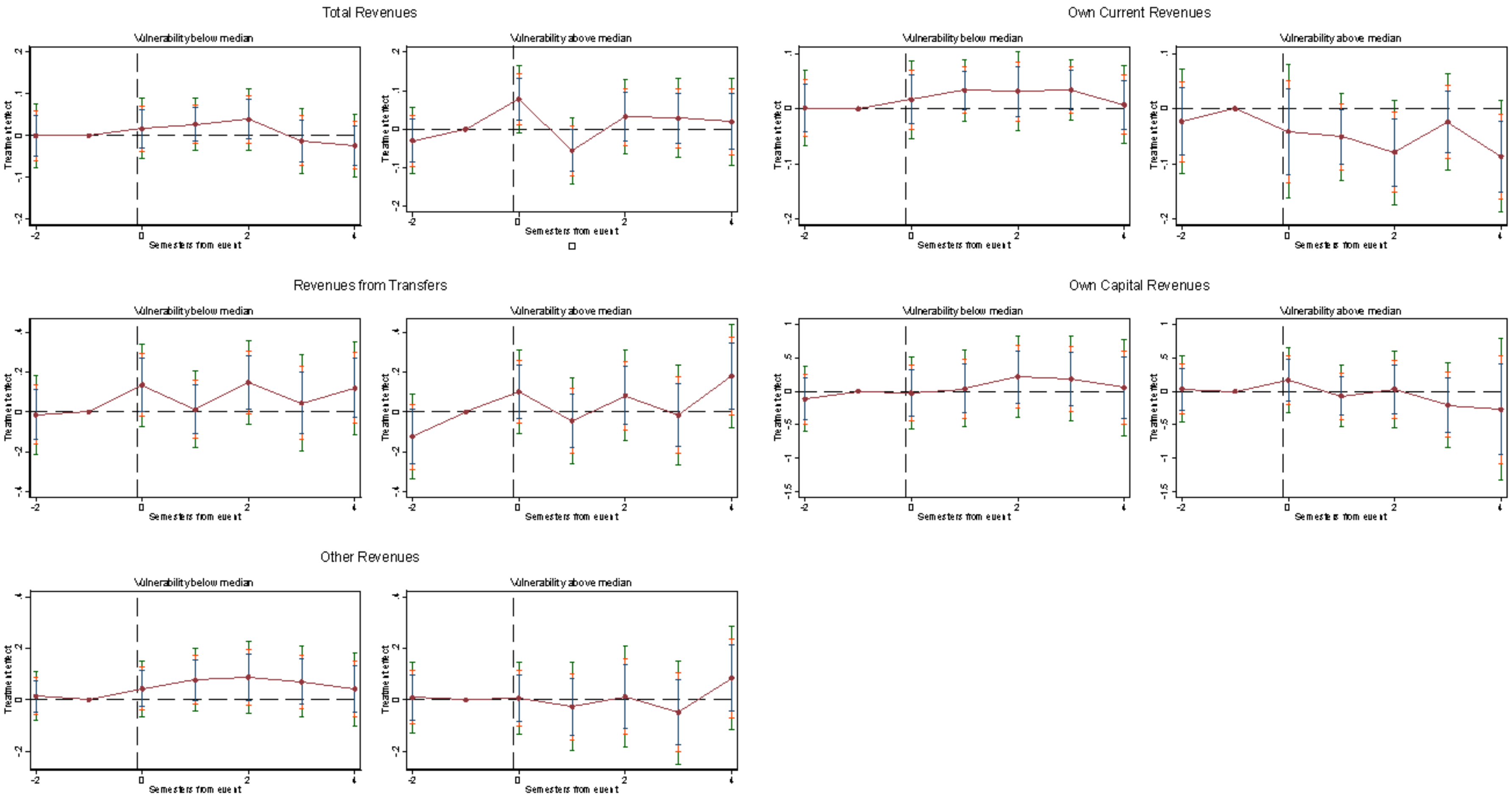
Focusing on revenues (Figure 8), by comparing less vulnerable treated municipalities with the corresponding counterfactual, we can see that the former experienced an increase in total revenues until the second semester after the event semester and then a decrease. We do find some peculiarities when considering vulnerability instead of resilience. In the aftermath of the flood, more vulnerable municipalities show an increase in revenues (not entirely explained by an increase in transfers, which is not statistically different from zero), while less vulnerable ones experience an increase in transfers. We also observe a negative and significant post-flood effect on own current revenues for more vulnerable municipalities; this might signal a higher impact of the flood in more vulnerable municipalities in terms of a reduced tax base (e.g., because of a reduction in the number of economic actors in the locale and/or prolonged tax cuts or exemptions).

Figure 7. Estimations by Vulnerability Level: Expenditures



Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

Figure 8. Estimations by Vulnerability Level: Revenues



Notes: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

6 Conclusions

Observing that a growing number of floods have affected Italy in recent decades and considering their impact on local economies, in this article we investigated the effect of flooding on the short-term budgetary choices of local (municipal) governments, focusing on 4,185 municipalities in nine Italian regions over the 2013–2016 period. We used a dynamic difference-in-differences model with an a priori identification of proper counterfactuals through propensity score matching.

On average, Italian municipalities respond to flooding events by fostering public investments; this expenditure growth is partly financed by increased transfers from other levels of government. This result highlights the capability of municipalities to cope with floods and react by boosting post-flood recovery. Moreover, the floods in question do not affect the tax base, and the municipalities do not change local tax rates. A system that is fully funded through taxation represents a sort of "bet with nature" that incentivises bad government behaviour, as taxation is seen as cost-neutral with respect to spending in loss prevention. As a result, governments forego prevention and mitigation activities (Modica et al., 2019a). Still, other ways of funding or financing sources aimed at meeting additional allocations might depend on the peculiar characteristics of the affected individuals and territories.

We extended our analysis to heterogeneous effects based on the ex-ante resilience and vulnerability of the municipalities in question. The results show that more resilient and less vulnerable municipalities can cope with unforeseen events because they can invest available internal budgetary resources. These municipalities do not have to wait for external aid. Less resilient and more vulnerable municipalities highly depend on transfers from other national and subnational levels of government.

Our findings have interesting policy implications. They can support policymakers in planning general disaster management as well as the relationship between national and local levels of government in disaster and reconstruction management. For instance, Italy is currently discussing a draft law on the adoption of a Code of Reconstruction. We believe that our results could make a pivotal contribution to this debate for at least two reasons.

First, as municipalities respond to floods by increasing their capital investments without an adjustment of their revenues, substantial imbalances can be generated in their financial budgets. This finding points to the need to grant some degree of flexibility to incur deficits in the aftermath of a disaster. Second, the prompt response in terms of increased capital expenditures appears to be larger for more resilient and less vulnerable municipalities. Therefore, the ex-ante capacity to cope with extreme events and limit damages is a good predictor of a municipality's post-disaster recovery capability. In this respect, the implication is not straightforward. On one hand, the long-term strategy for local and regional-national governments should be to enhance the resilience of municipalities and reduce their vulnerability. On the other hand, in the short term, there is room for direct intervention by the regional or national government in terms of direct capital spending in flooded, less resilient and more vulnerable areas. Relatedly, our findings highlight that the transfer of funds to local governments in less resilient and more vulnerable municipalities is not enough to boost local capital expenditures. This means that the failure to increase capital expenditures in these municipalities does not depend on tight financial or regulatory constraints but on the inability to operationalise additional spending in the short term.

This article can represent a starting point for future research. It would be very interesting to consider the political-economic mechanisms behind a municipality's budgetary dynamics by examining, for example, a mayor's characteristics and the electoral cycle. Furthermore, the econometric approach used here could be employed to estimate the effects of other extreme natural events, such as earthquakes, which also strongly affect the Italian peninsula. Finally, a similar approach could be applied to the private sector (i.e., firms) to investigate if it responds to extreme events in the same way as the public sector.

References

Amadio, M., Scorzini, A. R., Carisi, F., Essenfelder, A. H., Domeneghetti, A., Mysiak, J., Castellarin, A. (2019). Testing empirical and synthetic flood damage models: the case of Italy. *Natural Hazards and Earth System Science*, 19, 661–678.

ANCE/CRESME (2012). Città mercato e rigenerazione 2012. Analisi del contesto per una nuova politica urbana, Roma.

Bachner, G., Bednar-Friedl, B. (2019). The effects of climate change impacts on public budgets and implications of fiscal counterbalancing instruments. *Environmental Modeling & Assessment*, 24(2), 121-142.

Bakar, A. C., Larcker, D. F., Wang, C. C. Y. (2020). How much should we trust staggered difference-in-differences estimates? *Journal of Financial Economics*, 144(2), 370-395.

Benson, C., Clay, E. (2004). Understanding the economic and financial impacts of natural disasters. *Disaster Risk Management Series* No. 4, The World Bank.

Breckner, M., Englmaier, F., Stowasser, T., Sunde, U. (2016). Resilience to natural disasters—Insurance penetration, institutions, and disaster types. *Economics Letters*, 148, 106-110.

Cannizzaro, S., De Pascale, F., Farabollini, P., Muto, F. (2020). Introduction to the Special Issue "Socio-Natural Disasters and Vulnerability Reduction in the territorial ecosystems". *AIMS Geosciences*, 6, 1-5.

Chan, E. Y., Yue, J., Lee, P., Wang, S. S. (2016). Socio-demographic predictors for urban community disaster health risk perception and household based preparedness in a Chinese urban city. *PLoS currents*, 8.

CNI (2016). Accise e terremoti. CGIA Mestre, retrieved at http://www.cgiamestre.com/wp-content/uploads/2016/09/ACCISE-E-TERREMOTI.pdf

Cutter, S. L., Ash, K. D., Emrich, C. T. (2016). Urban–rural differences in disaster resilience. *Annals of the American Association of Geographers*, 106(6), 1236-1252.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, 18(4), 598-606.

Donnini, M., Modica, M., Salvati, P., Marchesini, I., Rossi, M., Guzzetti, F., Zoboli, R. (2020). Economic landslide susceptibility under a socio-economic perspective: an application to Umbria Region (Central Italy). *Review of Regional Research*, 40(2), 159-188.

EEA (2010). Mapping the impacts of natural hazards and technological accidents in Europe: An overview of the last decade. EEA Technical Report No 13. ISSN 1725-2237.

EEA (2016). Flood risks and environmental vulnerability – Exploring the synergies between floodplain restoration, water policies and thematic policies, https://doi.org/10.2800/039463.

Faiella, I., Natoli, F. (2018). Natural catastrophes and bank lending: the case of flood risk in Italy. *Bank of Italy Occasional Paper*, (457).

Franzi, L., Bianco, G., Bruno, A. Foglino, S. (2016). Flood Risk Assessment and Quantification in the Piedmont Region, Italy. In: Tiepolo M. "Planning to cope with tropical and subtropical climate change". De Gruyter Open Poland.

Hallegatte, S. (2014a). Natural Disasters and Climate Change. An Economic Perspective. Springer International Publishing Switzerland.

Hallegatte S. (2014b). Economic Resilience: definition and measurement. *World Bank Policy Research Working Paper* N. 6852.

Heipertz, M., Nickel, C. (2008). Climate Change Brings Stormy Days: Case Studies on the Impact of Extreme Weather Events on Public Finances. Available at SSRN: https://ssrn.com/abstract=1997256

Holling, C. S., (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, 4, 1-23.

IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. IPCC Sixth Assessment Report, ISBN 978-92-9169-159-3.

ISPRA (2021). Rapporto sulle condizioni di pericolosità da alluvione in Italia e indicatori di rischio associati, N. 353. ISBN: 978-88-448-1080-1.

Jerch, R., Khan, M. E., Lin, G. C. (2021). Local public finance dynamics and hurricane shocks. *NBER Working Paper* No. 28050.

Kahn, M. E. (2005). The death toll from natural disasters: the role of income, geography, and institutions. *Review of Economics and Statistics*, 87(2), 271-284.

Khan, N.A., Gao, Q., Abid, M. (2020). Public institutions' capacities regarding climate change adaptation and risk management support in agriculture: the case of Punjab Province, Pakistan. *Scientific Report*, 10, 14111.

Kirchmeier-Young, M. C., Zhang, X. (2020). Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences*, 117(24), 13308-13313.

Lis, E. M., Nickel, C. (2010). The impact of extreme weather events on budget balances. *International Tax and Public Finance*, 17(4), 378-399.

Marin, G., Modica, M. Paleari, S., Zoboli, R. (2021). Assessing disaster risk by integrating natural and socio-economic dimensions: A decision-support tool. *Socio-Economic Planning Sciences*, 77, 101032.

Martin, R. (2012). Regional economic resilience, hysteresis and recessionary shocks. *Journal of Economic Geography*, 12 (1), 1–32.

Melecky, M., Raddatz, C. (2014). Fiscal Responses after catastrophes and the enabling role of financial development. *The World Bank Economic Review*, 1-21.

Miao, Q., Hou, Y., Abrigo, M. (2018). Measuring the financial shock of natural disasters. A panel study of U.S states. *National Tax Journal*, 71(1).

Miao, Q., Chen, C., Lu, Y., Abrigo, M. (2020). Natural disasters and financial implications for subnational governments: Evidence from China. *Public Finance Review*, 48(1): 72-101.

Modica, M., Faggian, A., & Aloisio, R. (2019a). The Post-Earthquake Reconstruction in L'Aquila: Some Reflections. *Scienze Regionali*, 18(3), 515-522.

Modica M., Reggiani A., Nijkamp P. (2019b). Vulnerability, Resilience and Exposure: Methodological Aspects. In: Okuyama Y., Rose A. (eds) Advances in Spatial and Economic Modeling of Disaster Impacts. Advances in Spatial Science (The Regional Science Series). Springer, Cham.

Noy, I., Nualsri, A. (2011). Fiscal storms: public spending and revenues in the aftermath of natural disasters. *Environmental and Development Economics*, 16, 113-128.

Ostadtaghizadeh, A., Ardalan, A., Paton, D., Khankeh, H., Jabbari, H. (2016). Community disaster resilience: a qualitative study on Iranian concepts and indicators. *Natural Hazards*, 83(3), 1843-1861.

Parsons, M., Glavac, S., Hastings, P., Marshall, G., McGregor, J., McNeill, J., Stayner, R. (2016). Top-down assessment of disaster resilience: A conceptual framework using coping and adaptive capacities. *International Journal of Disaster Risk Reduction*, 19, 1-11.

Phaup, M., Kirschner, C. (2010). Budgeting for disasters: focusing on the good times. *OECD Journal on Budgeting*, 10(1), 1-24.

Pimm, S. L. (1984). The complexity and stability of ecosystems. *Nature*, 307, 321–326.

Raschky, P. A. (2008). Institutions and the losses from natural disasters. *Natural Hazards and Earth System Sciences*, 8(4), 627-634.

Rose, A. (2004). Defining and measuring economic resilience to disasters. *Disaster Prevention and Management*, 13 (4), 307-314.

Sarewitz D., Pielke R., Keykhah M. (2003). Vulnerability and risk: some thoughts from a political and policy perspective. *Risk Analysis*, 23(4), 805–10.

Taulbee, L. (2019). The Local Government Financial Response to Natural Disasters in Kentucky. MPA/MPP Capstone Projects, 330.

UNISDR (2009). UNISDR Terminology and Disaster Risk Reduction. UNISDR, Geneva, Switzerland.

WMO (2021). WMO atlas of mortality and economic losses from weather, climate and water extremes (1970–2019). World Meteorological Organization, Geneva, Switzerland, ISBN: 978-92-63-11267-5

Zampetti, G., Ottaviani, F., Minutolo, A. (2012). I costi del rischio idrogeologico, Dossier Legambiente, Roma, 2012.

Zhou, L. and Chen, Z. (2020). Are CGE models reliable for disaster impact analyses? *Economic Systems Research*, 20-4.

~~Fiscal policy~~The public finance response to floods of local governments ~~to floods~~ in Italy

Abstract

This paper aims ~~at~~to empirically ~~testing~~test the dynamics of budget outcomes of Italian municipalities in the aftermath of floods~~,~~ by accounting for heterogeneous levels of resilience and vulnerability to natural disasters. Our findings~~,~~ are based on a dynamic difference-in-~~difference~~differences model after propensity score matching~~,~~. They point to substantial impacts in terms of increased capital expenditure and revenues from ~~transfer~~transfers, which ~~also~~ depend on the degree of resilience and vulnerability. Through our analysis, we account for multiple aspects of risk ~~so we can~~to support policy decisions related to both ex-ante and ex-post disaster occurrence management.

Keywords: floods, fiscal policy of local governments, resilience, vulnerability
JEL codes: H2, H72, Q54

1 Introduction

Over the ~~last~~past 50 years, climate-induced disasters have accounted for about 50% of worldwide ~~recorded~~ disasters recorded on the EM-DAT database and over 70% of all economic losses, which have been estimated at about 3.7 trillion dollars (WMO, 2021). Even ~~if~~though scholars still do not ~~still~~ have the smoking gun that indicates the role of human activity in the ~~global~~ increasing global occurrence of small-scale extreme weather events ~~in recent times~~, a growing number of studies points to a causal link between climate change and ~~several extreme weather~~such events, ~~in particular~~especially extreme rainfalls that turn into flooding (WMO, 2021; Kirchmeier-Young and Zhang, 2020).

~~Nowadays~~Today, it is well ~~recognized~~recognised that ~~the~~ climate change (CC ~~henceforth~~) represents one of the most urgent and fundamental problems that ~~must be faced by both~~ public and private actors ~~in order~~must face to reduce the number of victims and injured from extreme climate-induced ~~disasters~~events as well as ~~the~~their associated economic costs~~, even in a perspective where CC is accelerating (increases in temperatures and global sea levels, more frequent extreme rainfalls and/or droughts). Overall, this context requires a coordinated action to fight the consequences of CC and to be prepared for future extreme events and hazards. Indeed,~~. CC is likely to exert a high ~~impact~~influence on future extreme natural events ~~that~~, which will ~~consequently~~ damage local areas and communities. However, the amount of ~~damages~~damage depends on the combination of the actual occurrence of hazards (probability and magnitude) and the ~~socio-economic~~ inherent socioeconomic characteristics of the affected areas ~~that~~, which can be proxied with the ~~(multi-faceted)~~multifaceted concepts of resilience, vulnerability and exposure (~~direct and indirect; see e.g.~~ Marin et al., 2021). For this reason, it would be more correct to talk about ~~‘~~“socio-natural ~~hazards’~~hazards” instead of ~~‘~~“natural ~~disasters’~~disasters” (Hallegatte, 2014a~~) as “*processes – slow or sudden – that are located in the intersection between “nature and society”, resulting from the interaction between a destructive agent (such as an earthquake, a tsunami, a hurricane, a flood) and the socio-cultural and environmental context on which it impacts*' (p. 2, Cannizzaro et al., 2020~~).

The damage arising from an extreme event ~~does~~depends not ~~depend~~only on physical factors ~~only~~ but also on the ability of local communities to be prepared for, face, mitigate and respond to the ~~catastrophic~~ event ~~too~~. Furthermore, the occurrence of natural disasters is ~~firstly~~initially faced by local public institutions ~~which~~that assess the risk and manage first emergency~~,~~

response, as well as search and rescue activities~~, and these~~. These capabilities are ~~strictly~~ connected with their level of proactivity~~.~~

~~In fact, the extant literature shows that under-prepared~~; underprepared areas~~, related to less pro-active institutions,~~ are the most damaged ones (Breckner et al., 2016; Chan et al., 2016; Kahn, 2005; Ostadtaghizadeh et al., 2016; Parsons et al., 2016; Raschky, 2008~~), while differences~~). Differences in the shock adaptation capacity ~~to adapt to a shock~~ may also vary according to spatial and geographical characteristics, such as ~~the~~an area's degree of rurality.[1] Therefore, even ~~if urgent actions to combat CC and its impacts are in charge of~~ though national and supranational entities are in charge of urgent actions to cope with CC impacts, local governments should rethink their climate risk assessment framework. This ~~accounts for~~framework should deal with mitigation and adaptation activities aimed ~~to prevent~~at preventing the effects that a changed climate might ~~exert~~have on local territories ~~in~~from an ex-ante perspective and ~~to help~~helping post-disaster recovery ~~in~~from an ex-post perspective.

However, most of the mitigation and ~~this is~~adaptation activities are also related to ~~the~~ healthy local public finance conditions~~.~~

~~However, despite few works have~~ and even though the literature has highlighted the impact of extreme ~~weather~~climate events on public finance (e.g~~.~~., Heipertz and Nickel, 2008; Lis and Nickel, 2010; Phaup and Kirschner, 2010~~) less~~), few studies have analysed the effect of selected impacts on government budgets (e.g., Bachner and Bednar-Friedl, 2019). ~~To our knowledge, little~~Little attention has been ~~given~~paid to the shocks generated by extreme climate events in terms of local public financing capabilities and fiscal policies. ~~In fact, we~~We argue that the areas that are more susceptible to ~~suffer harms by the~~suffering from a changed climate will necessarily drain resources ~~to~~from the local public ~~local~~ budget to prevent and mitigate ~~the risk~~risks and ~~to~~ recover after a shock affects them. This might be ~~particularly~~ detrimental ~~for 'recurrent'~~in the case of "recurrent" disasters, such as floods. ~~In~~Over the ~~last~~past decades, due to ~~increasing~~ global warming, floods ~~are capturing a~~have captured higher attention~~, given that they are constantly rising worldwide, in terms of~~ as their frequency, severity and intensity are constantly rising worldwide (EEA, 2010; IPCC, 2022). ~~From the EU to China, from India to the USA, floods have been responsible for hundreds of deaths and huge socio-economic damages, such as buildings, network (energy, communication and transportation) infrastructure, crops destruction, loss of livestock, worsening of health conditions (IPCC,~~

[1] As highlighted by Cutter et al. (2016), ~~the~~ economic capital is ~~much~~ more relevant ~~in increasing the resilience of urban areas, while social capital is much more important in~~ to increasing the disaster resilience of urban areas, while social capital is more important in enhancing the resilience of rural areas.

~~2022).~~ This ~~type of~~ hazard has underlined how major urban centres~~, which~~ that have not implemented an adequate risk assessment framework~~,~~ are the most damaged ~~ones~~areas (Benson and Clay, 2004). The ~~European Environmental Agency (~~EEA~~)~~ has estimated about 446 billion euros of economic losses caused by climate-related extreme events between 1980 and 2019. ~~By considering the increasing number of floods also in developed countries and the importance of local institutions in facing these events,~~

Given these premises, our work aims ~~at~~to empirically ~~testing~~test the dynamics of local governments' budgetary outcomes in the aftermath of floods in ~~Italy, that is a highly vulnerable country to flood (Faiella and Natoli, 2018).~~ ~~We take into account the~~a country that is highly vulnerable to such events – Italy (Faiella and Natoli, 2018). Italy is very susceptible to hydrogeological risks due to its geological, morphological and hydrographic characteristics. Moreover, illegal building, overbuilding and urbanisation represent other important drivers of risk. According to ISPRA (2021), almost 94% of Italian municipalities show high hydrogeological risk. Specifically, 7 million people, 13.4% of buildings and 84,000 cultural heritage sites are at flood risk. Moreover, according to the EM-DAT database, since the end of the 1930s, Italy has been one of the most damaged countries in terms of deaths, injured/affected people and damages due to extreme floods (54 disasters are reported). Main extreme events concern the entire Po River Basin; northern Italian regions, such as Emilia Romagna, Tuscany, Veneto, Lombardy and Liguria, are highly affected by floods. In 1951, the area of Polesine, the territory located between the lower course of the Adige and Po rivers up to the Adriatic Sea, had suffered the most dangerous flood of the last century: 239 deaths and around 3 million of damages have been recorded (EM-DAT). Overall, a 2012 study of ANCE/CRESME estimated that 61.5 billion euros of public funds were provided by the Italian government for recovery after hydrogeological events between 1944 and 2012 (about 1 billion euros per year), and the estimated costs are even higher (Zampetti et al., 2012). Italy is also the country with the largest absolute uninsured losses in the European Union (Amadio et al., 2019; Donnini et al., 2020; EEA, 2016). Therefore, quite often, the Italian government has funded reconstruction activities by imposing new taxes (e.g., excise duty on oil in 2009 after the L'Aquila earthquake; CNI, 2016). This is an issue for a country highly affected by several hazards, and it casts a shadow on the will of the Italian government to setup prevention and mitigation strategies. Therefore, we consider different ~~socio-economic~~levels of socioeconomic resilience and vulnerability ~~levels of the~~among Italian municipalities to infer whether their capacity to cope with disasters is ~~actually~~ affected by their ~~socio-economic~~

~~inherent~~socioeconomic characteristics. Understanding a municipality's fiscal response to disasters is fundamental given that some previous decisions about the allocation of financial resources and taxation can be changed (Benson and Clay, 2004; Tulbee, 2019~~,~~; Miao et al., 2020). ~~In detail, from~~On the ~~expenditure~~expenditures side, ~~it could be possible that~~ planned investments ~~or~~and ongoing projects ~~are~~might be postponed or abandoned, while new projects and ~~expenditure~~expenditures might be needed to cope with ~~emergency~~emergencies and post-event reconstruction. ~~From~~On the revenues side, local taxation provisions are generally ~~subjected~~subject to negative (tax cuts for post-event recovery or reduced tax base) or positive (additional transfers and taxation to ~~bear~~cope with new expenditures) changes (Benson and Clay, 2004).

~~Nowadays, works~~Currently, there are few studies on the impact of extreme climate~~-related~~ events on the financial and budgetary outcomes of public institutions ~~are scarce~~, especially at the subnational level (Faiella and Natoli, 2018). The ~~extant~~ literature ~~is especially devoted to analyse~~focuses on analysing the consequences of extreme ~~weather events~~hazards on fiscal policies at the country level, with mixed ~~evidence~~results (Heirpertz and Nickel, 2008; Lis and Nickel, 2010; Noy and Nualsri, 2011; Melecky and Raddatz, 2014; Miao et al., 2018). ~~Results~~The findings of this literature depend on ~~several~~the different aspects~~, such as the~~ that are considered (e.g., event severity ~~of events~~, country and ~~public governments'~~government characteristics, model assumptions and variables ~~that are considered.~~). For example, Noy and Nualsri (2011~~), by using~~) used a sample of 42 developed and developing countries ~~over~~in the 1990~~-~~–2005 period~~, have shown~~. In the case of developed countries, they found that natural disasters have a negative effect on revenues and cash surplus ~~of developed countries, while~~; they also recorded an increase ~~of governments payment~~in government payments and outstanding debt ~~is recorded. For~~. In the case of developing countries, all fiscal variables are negatively affected by extreme events, except ~~the~~ cash surplus. Similarly, Lis and Nickel (2010) ~~have asserted~~and Melecky and Raddatz (2014) found that less advanced ~~countries~~nations face a larger effect on public nominal budget ~~balance~~balances in the aftermath of ~~an~~ extreme ~~weather event than~~events compared to advanced economies. ~~Moreover, the fiscal impact of these events is higher for countries nearer the equator, due to warmer climate that characterises these countries as more vulnerable. Similar conclusions are obtained by Melecky and Raddatz (2014), who have classified countries depending on the level of credit and insurance markets' development. Few studies~~

However, few studies have analysed the fiscal response ~~after~~ in the aftermath of extreme climate events at the subnational level. Miao et al. (2020) ~~has~~ estimated the dynamic effects of several natural disasters on government finance in ~~thirty~~30 Chinese provinces ~~over~~in the period 1994~~-~~–2014. Their results suggest that expenditures and intergovernmental transfers increase in the aftermath of the event and then gradually decrease over time~~. This rise in public spending particularly refers to high income and wealthier provinces. Concerning revenues, they have demonstrated~~, while a limited effect ~~of natural disasters, while~~on revenues was found. Jerch ~~at~~et al. (2021) and Tulbee (2019) ~~analyse~~analysed the relationship between natural disasters and local (municipal/county) government finances in the ~~US. Specifically,~~ United States. Jerch et al. ~~(2021) focus their attention on hurricanes' effects on different municipal outcomes measures (expenditures, revenues and debt) at different aggregation levels. Their results show~~ (2021) found that hurricane exposure causes a decline ~~of~~in revenues and expenditures in the long run~~. This reduction is primarily connected to~~ as a result of the fall in local tax revenues. In the short run, the decrease ~~of~~in revenues is mitigated by ~~the~~ incoming ~~flows generated by~~ intergovernmental transfers. ~~Both results characterise municipalities with lower income and less educated population. Tulbee (2019), instead, estimates~~Tulbee (2019) examined the impact of extreme climate events (as declared by the ~~FEMA~~Federal Emergency Management Agency) on the fiscal ~~spendings~~spending and revenues of ~~Kentucky~~ counties in the state of Kentucky between 2007 to 2017. ~~Tulbee (2019) finds~~He found a significant increase in ~~the~~ intergovernmental transfers and a decrease in incoming taxes, while no significant change in ~~the~~ expenditures per capita ~~are recorded~~.

Considering the existing literature, we ~~constraint~~constrain our analysis to floods affecting municipalities in ~~9~~nine Italian NUTS2 regions in the 2013~~-~~–2016 period. To estimate the impact of floods, we have implemented a dynamic difference-in-differences approach coupled with propensity~~-~~ score matching over a panel of 4,185 Italian municipalities with monthly data. Since the ~~entity~~amount of ~~losses~~loss and the ability to react to extreme ~~natural~~climate events also depend on the ~~initial situation~~structural characteristics of each municipality, we have investigated ~~in depth~~ the effects of selected floods on budgetary outcomes by distinguishing ~~among high and low resilient and vulnerable~~ between municipalities~~.~~ with high and low resilience and vulnerability. To the best of our knowledge, our work is the first ~~that assesses~~to assess the impact of floods on budget outcomes ~~of local (~~at the municipal~~)~~ level by also analysing ~~the vulnerable and resilient~~ conditions of ~~the affected municipalities~~vulnerability and resilience.

Our results suggest that~~,~~ on average, Italian municipalities react to floods by ~~especially~~ increasing ~~capital~~ investments. This effect is not counterbalanced by adjustments in ~~their~~ revenues, so substantial imbalances could emerge. Through a deeper analysis of ~~municipality~~municipal budget breakdowns, we ~~have argued~~argue that the results greatly depend on the municipalities' degree of resilience and vulnerability~~ of municipalities themselves.~~. Specifically, we ~~have been able to~~ show that more resilient (and less vulnerable) municipalities ~~have a~~are better ~~capability~~able to face ~~extreme events~~floods because they can handle greater flows of already available resources~~,~~ without waiting for transfers from other government levels.

~~This paper is organised as follows. The next section provides the general framework for disaster management in Italy and discloses the strategy for relevant flood identification. Section 3 is devoted to the description of the empirical strategy. Disaster risk assessment and implemented propensity score matching are discussed in Section 4. Section 5 provides the main results and Section 6 concludes.~~

~~1 General framework for disaster management in Italy~~

2 The general framework for disaster management in Italy

In this ~~paper~~article, we focus on a specific policy implemented by the Italian ~~Government. We rely on~~government; that is, the decision ~~of~~by the Italian Council of Ministers ~~of~~on 28 July 2016 ~~that allocates~~to allocate funds for reconstruction interventions ~~of~~linked to 49 flooding events that had national relevance and affected ~~Italian~~the country's regions over the 2013–2016 period ~~2013 - 2016. More precisely, for~~. For all these ~~selected events~~events, a state of emergency was declared. According to Italian legislation, a state of emergency ~~was declared.~~
~~The state of emergency in the Italian legislation~~ can be declared ~~upon~~after the occurrence or in the imminence of exceptional events, such as extreme natural events ~~such as extreme events, e.g.~~ (earthquakes, floods, drought ~~or~~and, more recently, the Covid-19 pandemic~~. It~~). This state is strictly regulated by the law and ~~it is~~ declared by the Council of Ministers in agreement with the ~~Governors~~governors of the affected regions. The ~~declaration of the~~ state of emergency allows public authorities to act urgently and with extraordinary powers~~. They can protect citizens and repair any damage by~~ (i.e., derogating from ordinary legislation~~. Thus, the state of emergency declaration allows a delegate commissioner to recognize the amount of funds necessary for the immediate emergency but also the estimated funds for recovering from the~~

~~damages suffered by the affected territories. The state of emergency~~). This state lasts ~~12 months~~one year and can be extended ~~at most~~only for ~~12~~an additional 12 months. According to the Italian Civil Protection Department, a state of emergency has been declared in Italy more than 100 times since 2013.

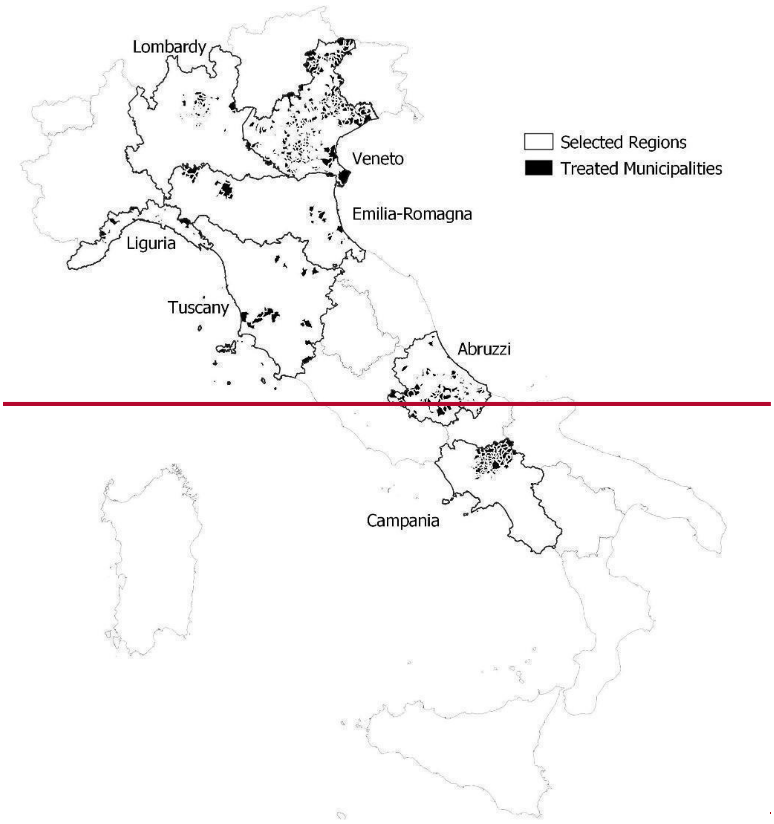
~~In this specific context, the~~The decision of the Council of Ministers allows for the compensation of ~~the damages related to~~costs suffered by private ~~assets~~citizens and economic ~~activities, specifically structural restoration of~~actors (e.g., repairing private buildings and ~~damaged~~businesses' structures, systems~~,~~ and equipment ~~of economic activities, for which the causal link between the damage suffered and the event is recognized, as well as~~), as well as for the purchase of stocks of raw materials, semi-finished and finished products ~~finished,~~that were damaged or destroyed due to the ~~events and no longer usable~~event.

The first set of activities ~~are thus~~is carried out by the ~~Head~~head of the Civil Protection~~, then~~; a regional delegate is ~~typically~~then appointed when the emergency phase ~~is concluded~~has ended. The Civil Protection system generally differentiates its activities by type of event and type of ~~Operative Centres~~operative centre according to the geographical ~~extension~~extent of the event. Overall, a hierarchical structure from ~~municipality~~the municipal to the national level is ~~structured~~put in place, with the ~~municipalities~~'local mayor acting as ~~first~~the authority responsible for the ~~preliminary civil protection~~initial activities~~.~~ of the Civil Protection.

We ~~have~~ analysed the Civil Protection and Delegate Commissioner ~~Ordinances~~ordinances providing ~~funds for~~ reconstruction ~~of~~funds in a selection of ~~the~~ 40 flooding events, and we ~~have~~ considered all the municipalities that have received funds.[2]

~~Figure 1. Selected Regions and Treated Municipalities~~

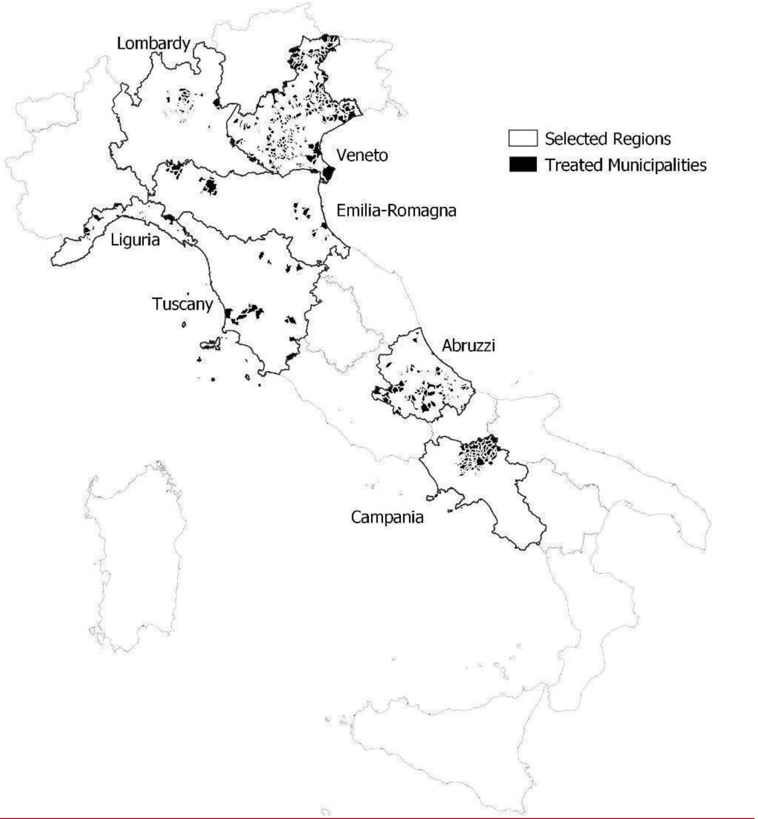
[2] As mentioned at the beginning of ~~Section~~section 2, the document of the Italian Council of Ministers ~~has~~ identified 49 flooding events, but~~,~~ for ~~9~~nine of them, the estimation of damages is not ~~fully~~ completed.



~~Note: Sardinia and Basilicata are not reported in the map due to the absence of treated municipalities~~

In our empirical analysis, we consider a municipality as treated whenever it receives reconstruction funds. For instance, for the events affecting the Campania region in 2015, we have ~~recognized~~recognised 152 treated municipalities ~~over 647. In general, we have just considered flooding events recognized as states~~out of ~~emergency~~647. Our starting sample includes 4,185 municipalities from ~~9~~nine Italian regions: ~~Abruzzi~~Abruzzo, Basilicata, Campania, Emilia~~-~~ Romagna, Liguria, Lombardy, Sardinia, Tuscany and Veneto. In this sample, 517 municipalities are classified as treated ~~and~~; their geographical distribution ~~among regions~~ is ~~reported~~shown in Figure 1.

Figure 1. Selected Regions and Treated Municipalities



Note: Sardinia and Basilicata are not shown on the map due to the absence of treated municipalities.

~~2~~3 Empirical strategy

~~Our~~We aim ~~is~~ to estimate the effect of floods on ~~local governments'~~municipalities' budgets by means of a dynamic difference-in-differences approach. ~~However, even if~~Even though we do not expect ~~any possible~~a risk of reverse causality between floods and local governments' budget outcomes, the likelihood that a flood occurs in a specific municipality generating ~~an number of~~ damages that ~~justifies~~justify the declaration of a state of emergency might be correlated with some attributes that also influence the dynamics of our outcome variables. For example, high-hazard local governments ~~in high-hazard areas~~ could increase their investments in the maintenance of water-related ~~infrastructures~~infrastructure (e.g~~.~~., reinforcement of levees) ~~in months prior to~~ before the usual flooding months ~~or that~~. Furthermore, the patterns of revenues and/or expenditures of more resilient municipalities ~~is~~are more (or less) smooth than the ones of less resilient ones. For this reason, we decided to identify a priori a proper counterfactual by matching treated municipalities to non-treated ones based on observable characteristics. Specifically, we estimate the propensity score as the predicted probability of being subject to a flood given the pre-treatment observable features of the municipalities and then match each treated municipality with one (or more) non-treated ~~ones~~municipality that has the closest probability of being treated. We then run a dynamic difference-in-differences model on the matched sample.

We exploit the high frequency (monthly) of our data on ~~local governments'~~ municipalities' revenues and expenditures to identify the short-term dynamics of ~~our~~the outcome variables in the aftermath of a flood. To limit the issue of seasonality, we group ~~together~~ time periods in semesters~~: instead~~. Instead of identifying ex-ante an arbitrary month as the beginning of the semesters (e.g~~.~~., January and July), for each event, we consider the first post-treatment semester to begin in the ~~exact~~ month when the flood occurred.[3]

~~More in detail, the~~ The difference-in-~~difference~~differences model ~~can be~~is expressed by the following equation:

$$\square_{\square\square} = \square_{\square} + \square_{\square} + \square_{\square\square} + \square_{\square-2}\square\square\square\square\square\square\square_{\square} + \sum_{s=0}^{3} \beta_{s+t}\square\square\square\square\square\square\square_{\square} + \square_{\square\square} \qquad (1)$$

where $\square_{\square\square}$ is the outcome variable for municipality $\square$ in the $\square$ semester; $\alpha_{\square}$ is the municipality fixed effect ~~to account~~that accounts (in a flexible way) for all time-invariant characteristics that could be correlated with both the outcome variables and the treatment; $\tau_{\square}$ is the semester fixed effect; $\gamma_{\square\square}$ is the calendar month dummy for month $\square$, which is allowed to exert a time-varying effect on the outcome variable to account for seasonality. The variable $\square\square\square\square\square\square\square_{\square}$ is the dummy variable that equals 1 for treated municipalities (as defined in ~~Section~~section 3) and 0 for untreated ~~(and~~ matched~~)~~ municipalities. We assume that the occurrence of a flood in municipality i in a specific month is exogenous (conditional on matching). The two sets of parameters of interest are $\eta_{\square-2}$ and $\beta_{\square+\square}$, which measure, respectively, pre-trends and the average effect ~~on~~for treated municipalities (ATT) on ~~municipalities'~~municipalities' budgetary outcomes. ~~They are indexed for the number of semesters, □, before and after the event semester.~~ The reference semester is the one prior to the event semester. Finally, $\varepsilon_{\square\square}$ represents the ~~independently and identically distributed~~IID error term.

---

[3] We consider semesters instead of months to account for the seasonality of local governments' expenditures and, especially, revenues. ~~Indeed, in~~In Italy, local governments collect or receive the bulk of their revenues in December and ~~in~~ June (i.e~~.~~., exactly six months ~~away one form the other~~apart). The definition of the beginning of the semester is specific to each treated municipality, depending on when the flood occurs. As for the non-treated (matched) municipalities, we align their time index to the one of the municipalities to which they are matched. For example, ~~image~~imagine that municipality A is subject to ~~the~~a flood in October 2014. Then, according to our propensity score matching procedure, municipalities B and C are matched to municipality A. ~~Then, the~~The time index t for the three municipalities will be set to 0 for the semester October 2014~~–~~–April 2015 (i.e~~.~~., the ~~"~~"event semester~~).~~"). This is a ~~peculiar~~particular application of a staggered difference-in-differences approach that accounts for the ~~critiques recently put forward~~recent criticism by Baker et al. (2022).

~~Table 1. Outcomes description~~

~~**Variable**~~	~~**Description**~~
~~*Total Expenditures*~~	~~Total monthly expenditures~~
~~*Current Expenditures*~~	~~Monthly current expenditures (personnel, raw materials and consumables procurement, service provisions, use of third party assets, current transfers, interests and financial charges, taxes and fees, extraordinary charges from current operations, loan repayment charges, expenses from services on behalf of third parties, payment to be settled).~~
~~*Capital Expenditures*~~	~~Monthly capital expenditures (real estate acquisition, expropriations and onerous easements, purchase of specific good for in-house production, use of third-party assets for economic activities, Acquisition of furniture, machinery and technical and scientific equipment, external professional appointments, capital transfers, shareholdings, capital contributions, granting of loans and advances).~~
~~*Total Revenues*~~	~~Total monthly revenues.~~
~~*Own Current Revenues*~~	~~Monthly current revenues (taxes and fees, public services revenues, income from the assets of the municipality, interests on advances and loans, net profits of special and participates companies, dividends of companies).~~
~~*Own Capital Revenues*~~	~~Monthly capital revenues (disposal of assets, debt collection, cash advances, short term loans, borrowing and lending, issuance of bonds).~~
~~*Revenues from Transfers*~~	~~Monthly revenues from transfers (capital transfers from state, regions, autonomous provinces, public sector, other subjects).~~
~~*Other Revenues*~~	~~Monthly other revenues (social security and welfare deductions for staff, withholding taxes, other deductions from staff on behalf of third parties, security deposits, reimbursement of expenses for services on behalf of third-party, repayment of advance payment of funds for the treasury service, deposits for contractual expenses, collections to be regularised).~~

~~Our selected dependent variables capture budgetary outcomes of the local (municipal) government. On one hand, since extreme weather events directly affect payments and public financing for disasters (Lis and Nickel, 2010), these measures provide information about the timing and type of policies that were implemented by municipalities in the aftermath of the flood. We have chosen three different variables in this respect: total expenditures, current expenditures and capital expenditures (i.e. public investments). More precisely, local governments react to extreme events by protecting people and by repairing public assets, so at first emergency costs should be borne. On the other hand, this type of events can indirectly affect the revenues side of local institutions' budgets, so their effect on different revenues variables is also considered. At the same time, local governments also have some room to intervene to increase or decrease local taxes by changing the local tax rates and by granting exceptional full tax exemptions in order to allow a quicker and prompt recovery of the economic activities and to (partially) refund suffered costs. Thus, in the aftermath of an extreme climate event, the structure of local governments' revenues can change, in terms of financial autonomy and transfers (Heirpertz and Nickel, 2008; Noy and Nualsri, 2011). By considering~~

~~these aspects, we consider the following revenue variables as dependent variables: total revenues, current revenues, capital revenues, revenues from transfers and other revenues. A detailed description of each dependent variable is reported in Table 1.~~

~~Information on monthly municipalities budgets is collected from the Bank of Italy "*Sistema Informativo delle Operazioni degli Enti Pubblici (SIOPE)*" dataset. Information is recorded with a monthly frequency on a cash basis. Given that information on the declaration of state of emergency refers to the period 2013-2016, our timespan covers up to 42 months.~~

~~3~~4 Disaster ~~Risk Assessment and Propensity Score Matching~~risk assessment and propensity score matching

~~The choice of the variables to be used in~~Concerning the estimation of the propensity score~~ is strictly ~~, the choice of the independent variables is connected with the concept of ~~extreme climate~~disaster risk. The risk of a specific climate-related disaster represents the probability of value losses in terms of different aspects, ~~especially in terms of ~~such as damages to economic activity and ~~wellbeing~~the well-being of ~~the ~~affected areas. The risk is thus a function of the vulnerability, resilience, exposure and hazard of the municipality under analysis (Hallegatte, 2014b~~,~~; Marin et al., 2021~~)~~). More formally, the risk for municipality *i* can be defined as:

$$\square_{\square} = \square(\square_{\square}, \square\square\square_{\square}, \square_{\square}, \square_{\square}) = \square_{\square} \times (1 - \square\square\square_{\square}) \times \square_{\square} \times \square_{\square} \quad (2)$$

where $\square_{\square}$ corresponds to the vulnerability of ~~the ~~municipality $\square$~~,~~; $\square\square\square_{\square}$ is its resilience~~,~~; $\square_{\square}$ represents its exposure, and H_i is the flood-specific hazard. ~~Each variable ranges between 0 and 1, so if at least one of them assumes~~If a~~ low value (or a high one for resilience), the obtained risk is low. Consequently, for example, in absence of flood hazard or exposure, risks are negligible or zero. Moreover, if a~~ municipality reaches a high resilience and/or a low vulnerability, ~~a ~~mitigation of risks occurs~~,~~ even in presence of high hazard probability and exposure, so the local system is expected to be weakly affected by a flood. Conversely, the risk is likely to be high when the municipality shows ~~a ~~low resilience and/or high vulnerability. A detailed explanation of how the indicators are built is found below.

~~In order to fully understand the framework and the meaning of these risk components, we here define the various components of Equation 2, as considered in the literature, and how we have measured them.~~

Vulnerability ~~(□□).~~ is defined as the set of ~~municipality's~~ characteristics of a municipality that can potentially generate ~~harms~~harm, independently of the flood risk ~~occurrence~~ (Sarewitz et al., 2003). ~~This concept is generally measured by a composite indicator since it can capture several facets of a local institution, such as wealth, level of urbanisation, population, public and private behaviours, entrepreneurs' strategies, financial and physical resources, etc. (Marin et al., 2021; Khan et al., 2020).~~ By adopting the same approach ~~of~~as Modica et al. (~~2019~~2019b) and Marin et al~~.,~~. (2021), a composite vulnerability index~~, which~~ was built that considers 17 municipality features~~, is built~~. Each feature ~~is~~was weighted with the number of times ~~the specific measure~~it was used in the literature to measure vulnerability. Each variable ~~has been~~was normalised to range between 0 and 1 ~~and,~~; then, the composite indicator ~~is~~was further normalised to range between 0 (low vulnerability) and 1 (high vulnerability). ~~Finally, in order to~~[4] To consider ~~the more important~~only relevant (discrete) differences ~~only among~~across municipalities, we ~~have implemented~~defined a dummy variable ~~for this measure, which equals~~equalling 1 ~~if~~when the ~~municipalities have~~municipality has a vulnerability higher than its median value~~,~~ and 0 ~~otherwise.~~ when this is not the case.

Resilience ~~(□□□□). is considered as~~is the ability of a system to resist, recover, renew and realign after disturbances or shocks (Pimm, 1984; Rose, 2005; Martin, 2012; Zhou and Chen, 2020). ~~The higher is~~As was the ~~level of resilience, the lower is the impact of shocks on the system. As~~case for vulnerability, resilience ~~is~~was measured by starting from a composite index following Modica et al. (2019) and Marin et al~~.,~~. (2021), which accounts for 13 ~~socio-economic~~socioeconomic variables.[5] Aggregation, weighting and normalisation ~~follows~~followed the same procedure used for vulnerability, leading to an indicator of resilience ranging from 0 (low resilience) ~~and~~to 1 (high resilience). As for vulnerability, we ~~have included~~defined a dummy variable ~~which equals~~equalling 1 ~~if~~when the resilience of the municipality is higher than its median value~~,~~ and 0 ~~otherwise.~~when this is not the case. Please note that ~~even if, conceptually,~~ vulnerability and resilience have two different meanings~~,~~ and that their theoretical relation is not univocal ~~and~~; rather, it depends on the ~~reference frameworks~~framework one adopts (see Cutter et al~~.,~~. 2008 for details). Without entering into

---

[4] For a complete description of the socioeconomic variables of the vulnerability index, see Table A.2 in Appendix A.

[5] ~~The indicator of resilience is composed of 13 variables: density of business; income; debt; poverty; homeownership; unemployment; productivity; sectoral dependence; government effectiveness; institutional capacity; education and health. Vulnerability is, instead, composed of 17 variables: extension of agricultural sector; dependence on agriculture; age; wealth; poverty; inequality; unemployment; institutional capacity; political rights; population pressure; urbanisation; building characteristics; ecosystem conversion; education; family structure; female condition and health.~~ For a complete description of the socioeconomic variables of the resilience index, see Table A.3 in Appendix A.

this debate, our research framework considers the two concepts as different ~~aspects. This~~though interrelated; this gives rise to distinct but quite strongly correlated indicators.

Exposure ~~(□ _).~~ can be ~~identified~~defined as~~ the set of~~ all the assets and the population that ~~can~~may be affected by a hazard (Hallegatte, 2014b). It includes ~~socio-economic~~socioeconomic and ~~geographical/physical~~geophysical features of municipalities. ~~Municipality level of~~ A municipality's exposure ~~has been~~was quantified by collecting ~~socio-economic~~socioeconomic and geographical data from different ~~data~~ sources. From the ~~socio-economic~~socioeconomic perspective, population numbers and households' taxable income ~~have been~~were considered~~. These data have been obtained by the Italian National Institute for Statistics (~~ based on ISTAT~~)~~ and ~~the Italian Department~~Ministry of Economy and Finance ~~(MEF) database~~data, respectively.[6] ~~Concerning~~We also took into account the following geographical characteristics~~,~~ ~~a set of three variables have been considered~~ of the municipalities: altitude~~,~~ (metres above sea level), coastal/island classification ~~and land area. Altitude is conventionally measured as the location, in terms of metres over sea level, of the municipality's city hall. Referring~~(proximity to ~~coastal or island classification, being a coastal municipality requires that part of the territorial area overlooks~~ the sea ~~while, if a municipality is classified as an island, the area is~~ or surrounded by the sea~~. Finally, the land area defined by the administrative units' boundaries corresponds to the area of a municipality~~) and ~~it is~~ area (measured in square kilometres~~. Data on 15th ISTAT Census, which refers to 2011, are considered for measuring these exposure variables.~~).

Hazard~~ (□ _). It~~ is the probability of occurrence of an extreme event that can create perturbations to the economic system. In our study, ~~as above-mentioned,~~ the hazard ~~specifically~~ refers to floods. The flood probability ~~of occurrence~~ for each municipality ~~is~~was measured as the share of the total area at risk of ~~floods~~flooding (hydrological risk). ~~Three~~ISPRA has identified three degrees of hydrological risk~~ have been identified by ISPRA~~: high probability ~~scenario~~, with a return period of 20~~–~~–50 years (frequent floods~~),~~); medium probability~~ risk~~, with a return period of 100~~–~~–200 years (less frequent floods~~)~~); and low probability~~ risk~~ of floods or other extreme events (ISPRA, 2021). The hazard measure ranges between 0 and 1 according to the area that lies in each of the three groups, and a weighted average ~~has been~~was calculated and ~~again~~also normalised between 0 and 1 ~~in order~~ to get a comprehensive flood hazard

[6] Concerning households' taxable income, the ~~MEF~~ database ~~supplies~~of the Ministry of Economy and Finance provides information on the sum of incomes declared by residents of the municipality ~~to be~~that is subject to the general income tax for individuals (IRPEF). ~~We include the lagged value of income in~~In our estimation of the propensity score, we included the lagged value of this income.

variable ~~of~~for the municipality. In our estimation of the propensity score, the municipality risk variables (vulnerability, resilience, exposure and hazard) are considered to be time-invariant.[7] ~~Municipality risk variables (vulnerability, resilience, exposure and hazard) are considered as time-invariant covariates in our estimation of the propensity score.[8] Moreover, to~~To account for possible differences in the pre-trends of the outcome variables between treated municipalities and controls, we estimate a separate propensity score for each dependent variable, including as a covariate the ~~6~~six-month change in (log) outcome prior to ~~the~~ treatment. Finally, as we also want to provide evidence about the heterogeneous effect for municipalities with different levels of resilience and~~/or~~ vulnerability, we also interact these pre-trends with our dummies for resilience and vulnerability. ~~With the aim of being~~To be as flexible as possible in the identification of good matches, we estimate each probit separately for each month ~~where~~when at least one event occurred.[9]

Table ~~2~~1. Propensity Score Matching ~~variables description~~Variables Description

Variable	**Description**
Population	Annual resident municipal population on 1st January.
Income	Lagged per capita general income tax IRPEF.
Land Area	Area of a municipality expressed in square kilometres.
Altitude	Metres over sea level of the municipality's city hall.
Island	Dummy equals 1 if part of the territorial area of the municipality overlooks the sea, 0 otherwise.
Coastal	Dummy equals 1 if the municipality area is surrounded by the sea, 0 otherwise.
Resilience	Dummy equals 1 if the resilience of the municipality is above or equal to the third quartile, 0 otherwise.
Vulnerability	Dummy equals 1 if the vulnerability of the municipality is above or equal to the third quartile, 0 otherwise.
Hazard	Share of the total area (in squares kilometres) at hydrogeological risk.

We match each treated municipality to the two nearest neighbours in terms of predicted propensity score and impose a *caliper* to limit the bias arising from ~~'bad'~~bad matching.[10] ~~An exact~~Exact matching between treated and controls in terms of resilience and vulnerability is imposed.[11]

[7] In contrast, income and population are time-varying variables. However, given that we only have information on yearly change and the high persistence of these variables, we included them in our propensity score with a 1 year.

~~[8] Income and population, instead, are time-varying variables. However, given that we just have information on yearly change and the high persistency of these variables, we include them in our propensity score with a 1 year.~~

[9] February 2014, March 2014, September 2014, October 2014, November 2014, February 2015, March 2015, September 2015~~,~~ and October 2015. ~~Results~~The results based on a single propensity score for all the events are very similar to the ones reported in the ~~paper~~article and ~~remain~~are available upon request.

[10] We apply the usual rule of thumb to set the caliper to 1/4 of the standard deviation of the predicted propensity score.

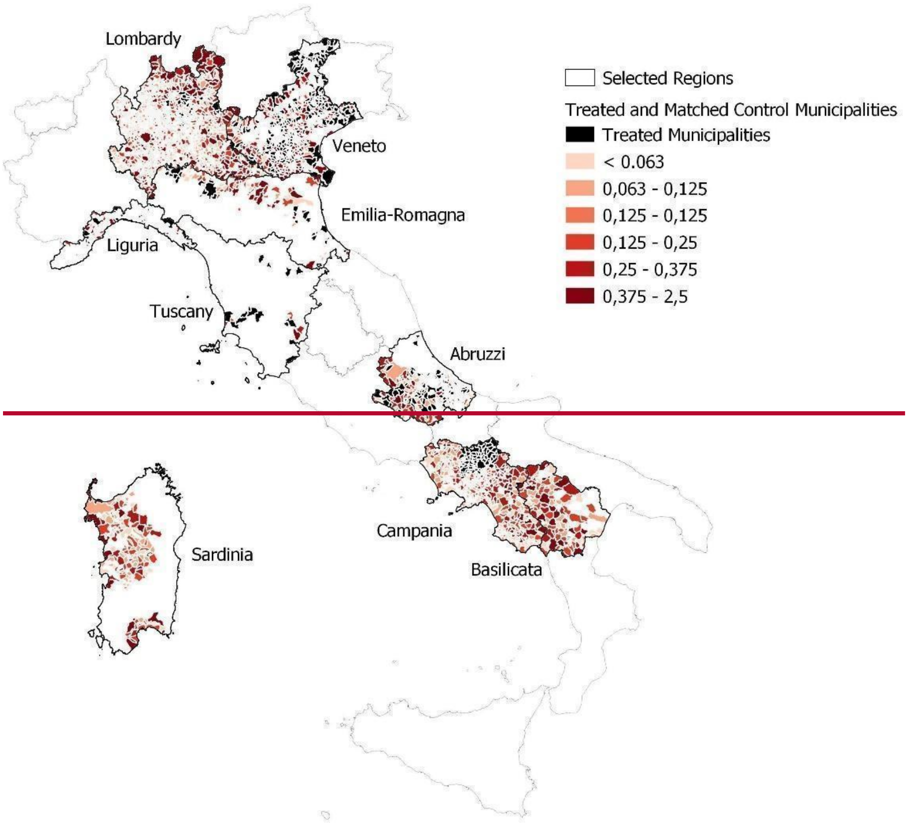
[11] As an additional robustness check, we add one additional dimension to the exact matching~~,~~; that is, the quartile of the outcome's ~~6-months~~six-month pre-trend. ~~Results~~The results are reported in Appendix ~~B~~C.

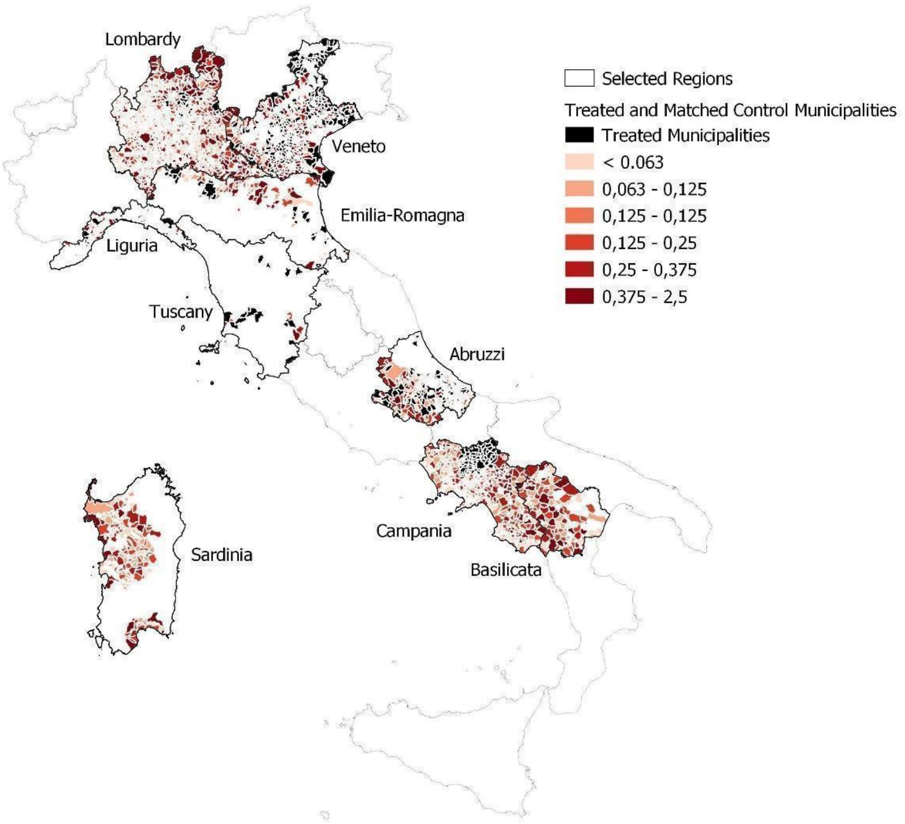
To test the validity of the matching based on the propensity score, we test whether treated and controls share the same average characteristics by means of a simple t-~~tests~~test. We contrast these mean comparisons with a mean comparison between treated municipalities and all (~~both~~ matched and unmatched) untreated municipalities~~,~~ to understand whether the matching improves ~~the~~ homogeneity in the two groups of treated and controls. ~~Results,~~ Our results are reported in Appendix ~~A~~B, Tables ~~A~~B.1.1 and ~~A~~B.1.2~~,~~. They suggest that the matching ~~reduces~~ substantially reduces the bias that could arise if municipalities with systematically different characteristics ~~would have~~had systematically different trends in the outcome variables. ~~Overall, all~~All the observable characteristics ~~are not statistically different~~show no statistical difference, on average, between treated and matched municipalities at conventional levels of statistical significance after matching on the propensity score. Instead, if we consider all the untreated municipalities as control groups, the differences were generally significantly different from zero ~~if we considered all untreated municipalities as control groups~~ (see Table ~~A~~B.1.1).

Figure 2 maps treated and matched control municipalities. There are 517[12] treated municipalities and, based on propensity score matching, 2,117 matched control municipalities (for at least one outcome variable).

Figure 2. Treated and Matched Control Municipalities

[12] Specifically, the whole sample of treated municipalities has 785 observations. Despite this, we only account for 517 because their pre- and post-trends can be fully observed in our reference period (2013–2016). In this way, we avoid the risk of including in the pool of non-treated municipalities those that were affected by flooding prior to 2013 or after 2016, for which we do not have information.





Note: Treated municipalities are filled in black. Matched control municipalities are filled with different shades of red~~,~~ to account for the average contribution (weight) of each municipality to the building of the counterfactual across all different events and outcome variables.

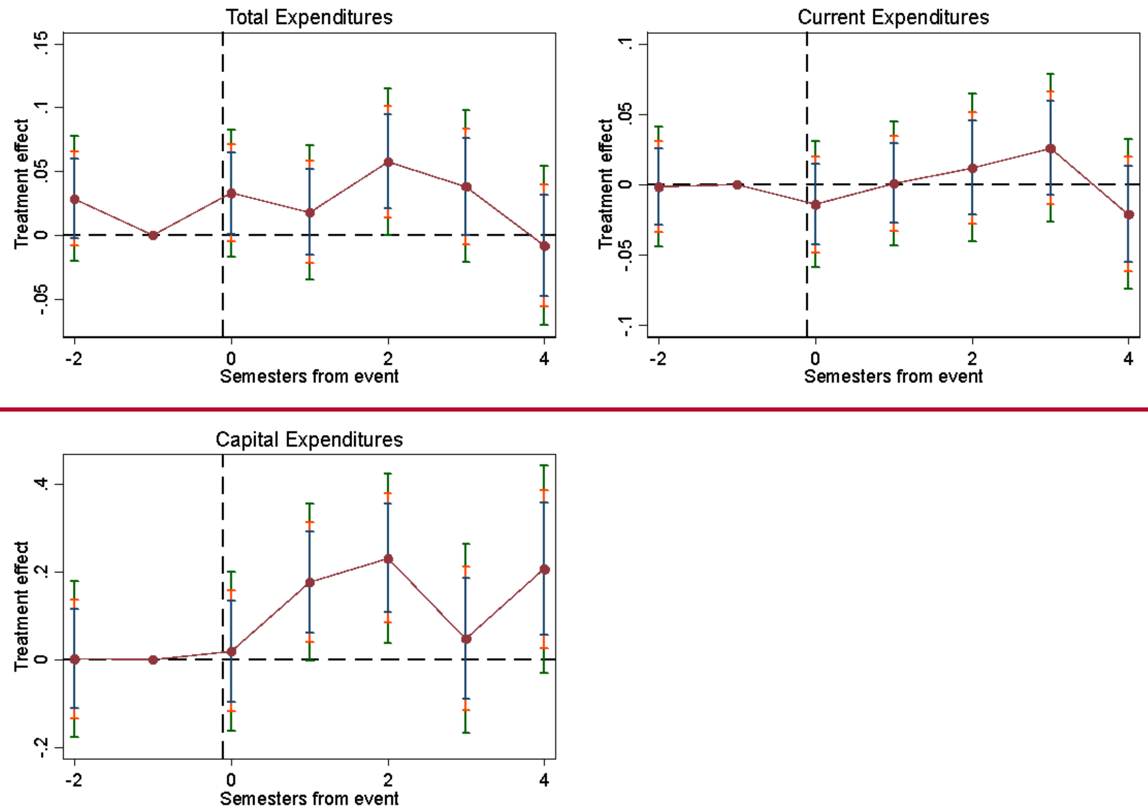
~~Figure 2 maps treated and matched control municipalities. As underlined in Section 2, treated municipalities are 517[13] while, by estimating propensity score matching, we have identified 2,117 matched control municipalities (for at least one outcome variable).~~

~~4~~5 Results

~~4.1~~5.1 Baseline results

The dynamics of our estimated average treatment effect of floods on municipalities' budgetary outcomes ~~is~~are reported in ~~Figure~~Figures 3 (expenditures) and 4 (revenues). ~~Overall~~Generally speaking, no significant pre-trend exists, ~~which allows us to consider~~so any post-treatment deviation of the trends between treated municipalities and the counterfactual ~~as an additional effect induced by the flood~~could be ascribed to the extreme event.

~~Figure 3. Difference-in-differences baseline estimations – Expenditure~~

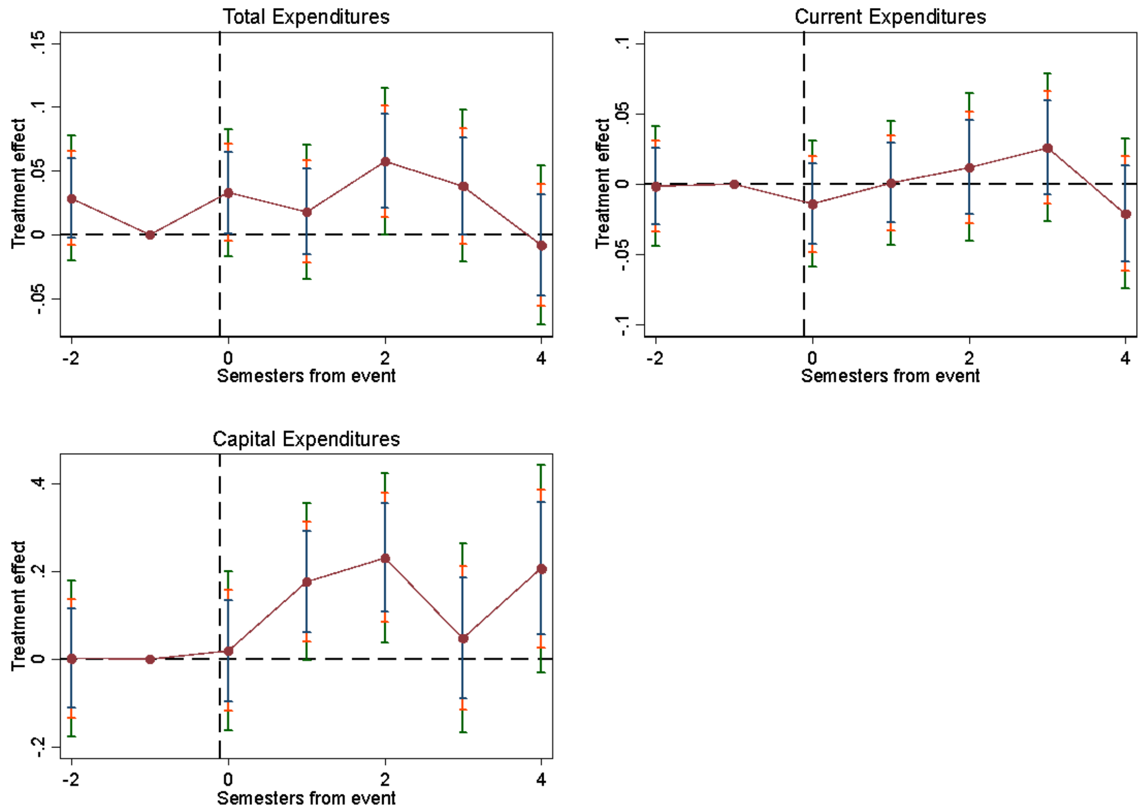


~~Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.~~

~~[13] Specifically, the whole sample of treated municipalities has 785 observations; despite this, we account for 517 treated municipalities only because their pre and post trends can be fully observed in our reference period 2013-2016. In this way, we avoid the risk of including in the pool of non-treated municipalities those that were affected by a flood prior to 2013 or after 2016, for which we have no information.~~

In all the figures, when “semesters from event” equals 0 (t~~=~~ = 0), we are referring to ~~‘~~the “event ~~semester’.~~semester.” The treatment effect on total expenditures is positive until the third semester after a flood~~ and then~~; it ~~goes back~~reverts to zero in the fourth semester. In terms of magnitude, the effect is sizeable: from +3.4~~ percent~~% in the event semester ~~up~~ to +6~~ percent~~% in the third post-treatment semester. ~~For what concerns~~Regarding the precision of the estimates, the effects are statistically different from zero in the event semester (p-value~~<~~ < 0.1~~),~~) and the second (p-value~~<~~ < 0.01) and third (p-value~~<~~ < 0.1) semesters. These results indicate that local governments react to ~~floods~~flooding quite soon by increasing expenditures, even though the full potential is reached ~~1~~one year after the flood~~ occurrence~~. However, it seems that this effect tends to fade away quite rapidly.

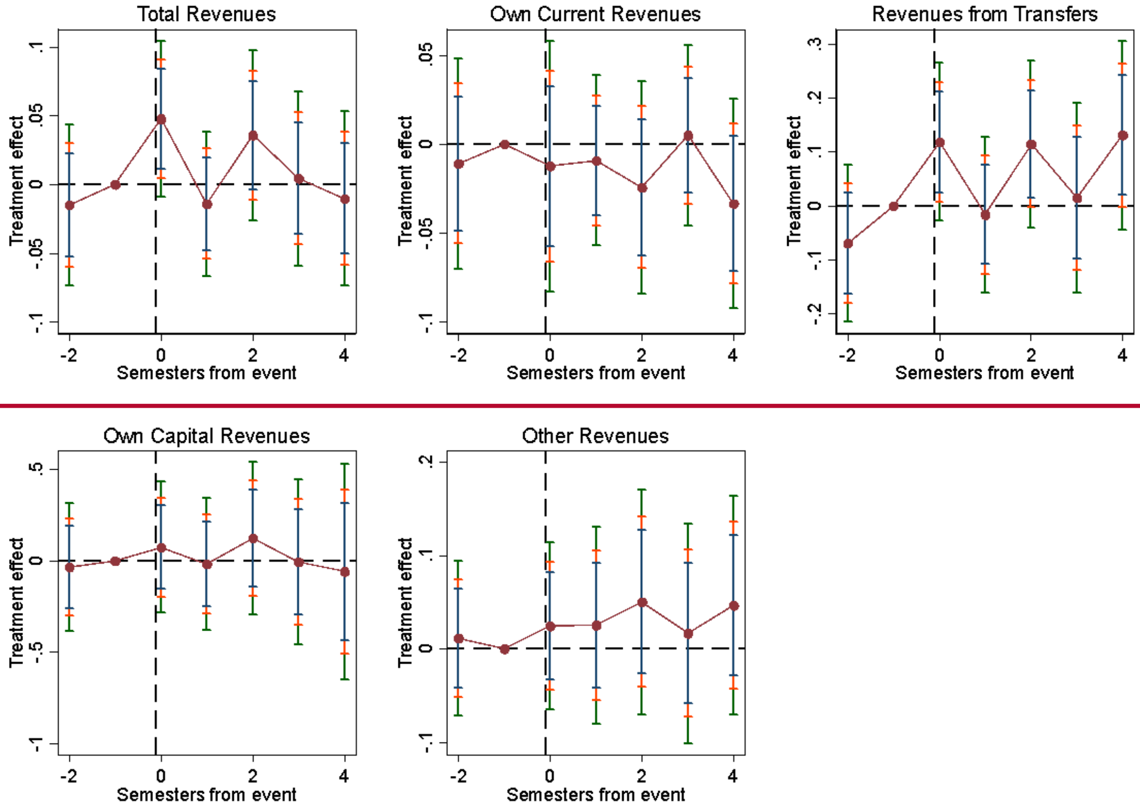
Figure 3. Difference-in-differences Baseline Estimations: Expenditures



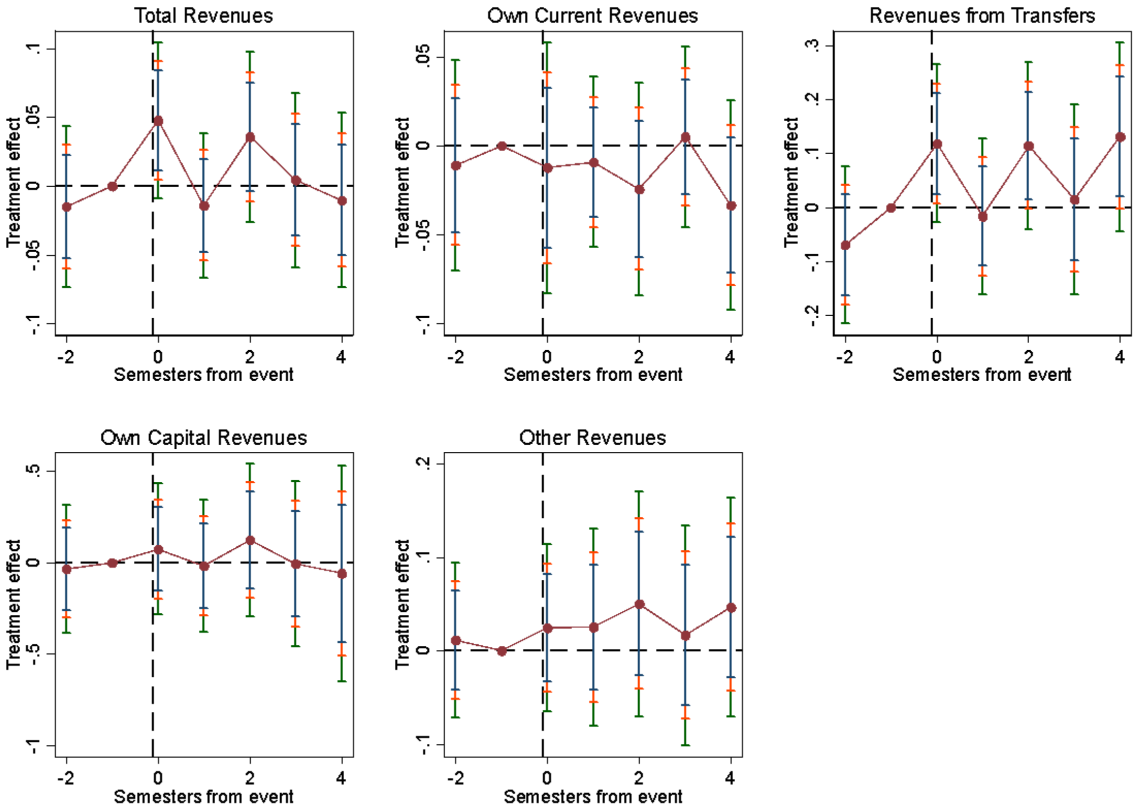
Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

To dig deeper into the drivers of this overall effect, we consider expenditures in fixed capital (i.e., investments) and current expenditures separately. Public investments represent a large part of expenditures aimed at boosting the recovery and reconstruction of infrastructure and buildings that were directly hit by the flood. The effect of ~~floods~~a flood on capital expenditures (bottom-left panel of Figure 3) only shows up in the second semester ~~(t=1)~~ after the flood (t = 1) and further grows in the third semester (t~~=~~ = 2). This effect is statistically different from zero (p-value~~<~~ < 0.1) and quite large in magnitude~~:~~; it corresponds to an increase (compared to the counterfactual) of 19~~ percent~~% in the second semester and 26~~ percent~~% in the third semester. Considering current expenditures (e.g~~.~~., personnel expenditures), we ~~do not~~ find ~~any~~no significant effect on treated municipalities in the aftermath of a flood~~ and~~; this might ~~be the~~ signal that climate disasters provoke immediate impacts on ~~the~~ municipal capital and physical assets~~ that~~, which wear off when these assets are replaced.

Figure 4. Difference-in-differences ~~baseline estimation~~ Baseline Estimation: Revenues


Total Revenues
Own Current Revenues
Revenues from Transfers
Own Capital Revenues
Other Revenues
Treatment effect
Semesters from event

~~Notes: three~~


Total Revenues
Own Current Revenues
Revenues from Transfers
Own Capital Revenues
Other Revenues
Treatment effect
Semesters from event

Note: Three levels of statistical significance are reported~~. Blue~~: p-value~~<~~ < 0.1~~; Orange~~ (blue), p-value~~<~~ < 0.05~~;~~ ~~Green~~ (orange), and p-value~~<~~ < 0.01~~.~~ (green).

~~Focusing~~When focusing on revenues (Figure 4), we observe that the effect of floods on total revenues is characterised by a non-monotonic trend. An instantaneous (t~~=~~ = 0) significant increase ~~of~~in total revenues happens when the shock occurs, ~~corresponding~~which corresponds to a +4.9% increase (significant at 5~~%); this~~%). This effect is immediately reabsorbed in ~~the following semester (~~t~~=~~ = 1~~)~~. In the third semester (t~~=~~ = 2), revenues are subject to a new increase (not statistically significant) and then start to steadily decline.

By adopting the same approach ~~of~~as with expenditures, we break down ~~the~~ total ~~revenues value~~revenue into its main components. Interestingly, no significant effects are found for ~~own~~ current ~~revenues~~, capital ~~revenues~~ and other revenues. ~~This is in line with Miao et al. (2020), who find no statistically significant impact of floods on fiscal outcomes in Chinese provinces.~~ However, when considering revenues from transfers, we estimate a positive and significant impact in the event semester and the third semester. This effect suggests that at least part of the additional expenditures ~~born~~borne by local governments ~~are~~was financed by national or other subnational governments. At the same time, it seems ~~like~~that local governments do not significantly change their ~~own~~ revenues by suspending or postponing the collection of local taxes to support the different economic agents (citizens, workers, companies) affected by ~~the flood~~flooding. Furthermore, floods do not seem to have a substantial (positive or negative) influence on the local tax base.

~~In sum,~~Therefore, the system seems to be based on central government transfers to meet the necessary additional allocations. This could encourage free riding if local ~~governments~~institutions choose not to invest in prevention and mitigation, especially by considering that imposing new taxes on the territories affected would turn into a sort of fiscal punishment that is going to be added into the costs already generated by an event. To summarise, in Italy, flooded municipalities ~~in Italy~~ tend to respond ~~to extreme events~~ by boosting the level of public ~~investments~~investment (with a ~~6-months~~six-month delay~~)~~), which ~~are~~is financed (at least partly) ~~financed~~ by increased transfers from other levels of government. This result suggests a good capacity to cope with extreme events and ~~to~~ act with the aim of ~~boosting the~~enhancing post-flood recovery. ~~On the other hand~~In contrast, no change is observed in terms of current ~~expenditure~~expenditures and ~~in~~ other revenues, which means that the ~~considered~~ events in question did not ~~erode~~ substantially erode the tax base and that local governments did not change local tax rates.

~~4.2~~5.2 *Heterogeneous effects: high- vs~~.~~ low~~-~~-resilience municipalities*

Since municipalities ~~could~~ react differently to extreme ~~natural~~climate events depending on their characteristics, we provide evidence about the effect's heterogeneity ~~of the effect depending~~based on the level of resilience and vulnerability. ~~Standard~~Most studies ~~on~~of economic resilience and vulnerability~~, often provide~~ support ~~for~~ the ~~statement~~notion that ~~any kind of system, even the socio-economic one, would~~ a system's ability to react to and cope ~~to~~with shocks~~, more or less well,~~ varies according to ~~given~~its characteristics~~ of the system itself. Thus, empirical studies analysed systems by looking at selected proxies – of economic, resilience and vulnerability – and if their performances were positive in the aftermath of a shock, then scholars argue that these systems are resilient and not vulnerable.~~. However, to our knowledge, ~~there are not many~~few studies ~~that show~~have shown the actual mechanism through which a resilient system is better able to cope with ~~unpredicted~~unexpected shocks. In our work, we show how the ex~~-~~-ante more resilient and less vulnerable municipalities are able to cope with unforeseen events through their ~~better~~ capacity to better use internal budgetary resources, while less resilient and more vulnerable municipalities mostly depend on ~~state~~ transfers. Overall, our work ~~is a sort of~~may be considered an explicit test of the ~~resilient~~ capacity of resilient municipalities to cope with unpredicted shocks~~.~~ and the ensuing socioeconomic vulnerability.

We consider the median value of resilience and vulnerability~~, respectively,~~ as the threshold to identify high- vs~~.~~ low~~-~~-resilience/vulnerability municipalities. As shown in Table 2, 35.20% of treated municipalities are highly resilient and less vulnerable to floods. Less resilient and more vulnerable damaged municipalities are similarly represented in the sample (38.88%). The residual 26% is ~~equally~~ distributed between less resilient/less vulnerable (14.12%) and ~~high~~highly resilient/~~high~~highly vulnerable (11.80%) treated municipalities.

Table 2. Treated Municipalities by ~~vulnerability~~Vulnerability and ~~resilience level~~ Resilience Level

Resilience/Vulnerability	Low	High	**Total**
Low	**73** 14.12%	**201** 38.88%	**274** 53%
High	**182** 35.20%	**61** 11.80%	**243** 47%
Total	**255** 49.32%	**262** 50.68%	**517** 100%

~~As a first step~~First, we ~~consider the breakdown of~~break down our sample by resilience~~:~~; the results are reported in Figures 5 (expenditures) and 6 (revenues). ~~Overall~~In general, less resilient municipalities hit by floods do not change their pattern of (total, current and capital) expenditures~~.~~; the effects are not statistically different from zero, with the sole exception of ~~an~~the increase ~~of~~in total expenditures in the second semester ~~post~~after the event semester (~~at conventional 5%). On the other hand~~p-value < 0.05). In contrast, we find large and significant effects for resilient municipalities, especially ~~so~~ for capital ~~expenditure~~expenditures and total ~~expenditure, while~~expenditures; we also estimate a positive and significant effect on current ~~expenditure~~expenditures in the third post-treatment semester. In ~~sum, flooded~~summary, municipalities with high resilience respond quite promptly to ~~the flood~~flooding by boosting spending in infrastructures and other capital expenditures to favour post-disaster recovery. Moreover, these municipalities also boost current expenditures in the ~~longer~~long run~~, while the~~. The response to floods of less resilient municipalities is much weaker. ~~Indeed, this~~This is one of the first pieces of evidence~~,~~ that shows the mechanism through which more resilient ~~(and less vulnerable)~~ municipalities are better able to ~~better~~ face extreme events ~~through~~thanks to their higher capacity to handle greater flows of (internal) resources, without waiting for external ~~aids. In some sense, this is a process that is similar to the one experimented in Emilia-Romagna region after the earthquake of 2012.~~aid. This ~~area is characterised by high resilient municipalities and, as stated by the President of the General Federation of Italian Commerce and Tourism of Emilia Romagna (Confcommercio), "The recovery was the result of a synergy between public and private. The entrepreneurs immediately invested in the restart, without waiting for public funds which, after following the bureaucratic process, arrived anyway".[14] This evidence~~ highlights two important ~~points~~findings of this work: 1) more resilient subjects have a higher capacity to quickly spend money, thereby immediately starting the recovery process; 2) more resilient subjects are more aware that investments are important to facilitate ~~the~~ post-disaster recovery.

~~Results~~The results for revenues, broken down by level of resilience and revenue type (Figure 6), indicate that less resilient treated municipalities record a statistically significant (~~at~~ p-value < 0.1~~%)~~) and substantial increase ~~of~~in total revenues in the semester of the flood with respect to the corresponding counterfactual, which is mostly driven by a substantial increase in transfers from higher or equal levels of government. This does not happen~~, instead, for~~ to more resilient municipalities, for which we find no immediate ~~increase~~rise in total revenues and a smaller (and not significantly different from zero) increase in transfers compared to less

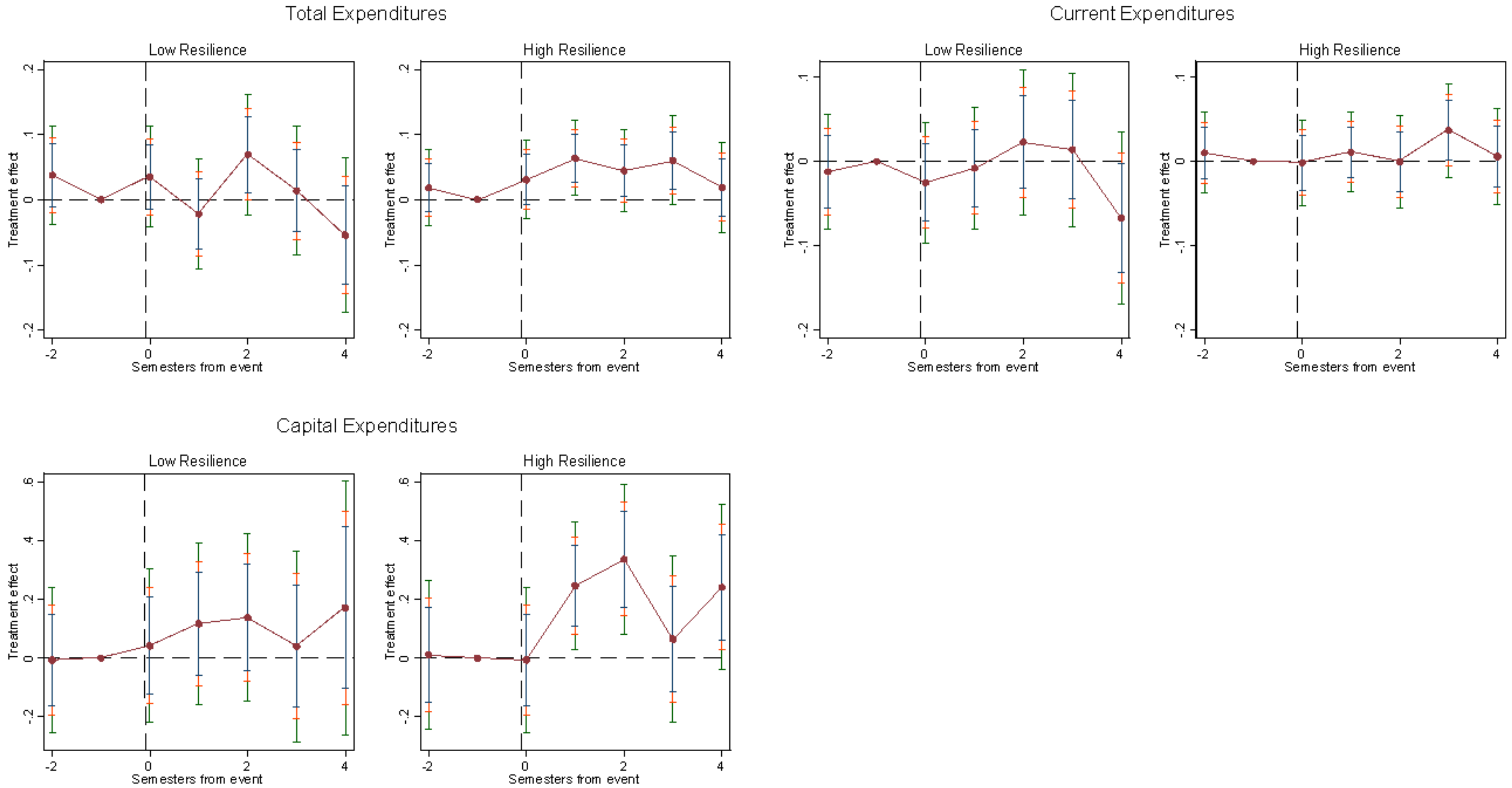
~~[14] Available in Italian only here: https://www.quotidiano.net/inchieste/terremotoemilia/la-ripartenza/~~

resilient ones, while some evidence of a significant increase in transfers appears in the last observed semester~~ only~~.[15]

~~In sum, our~~

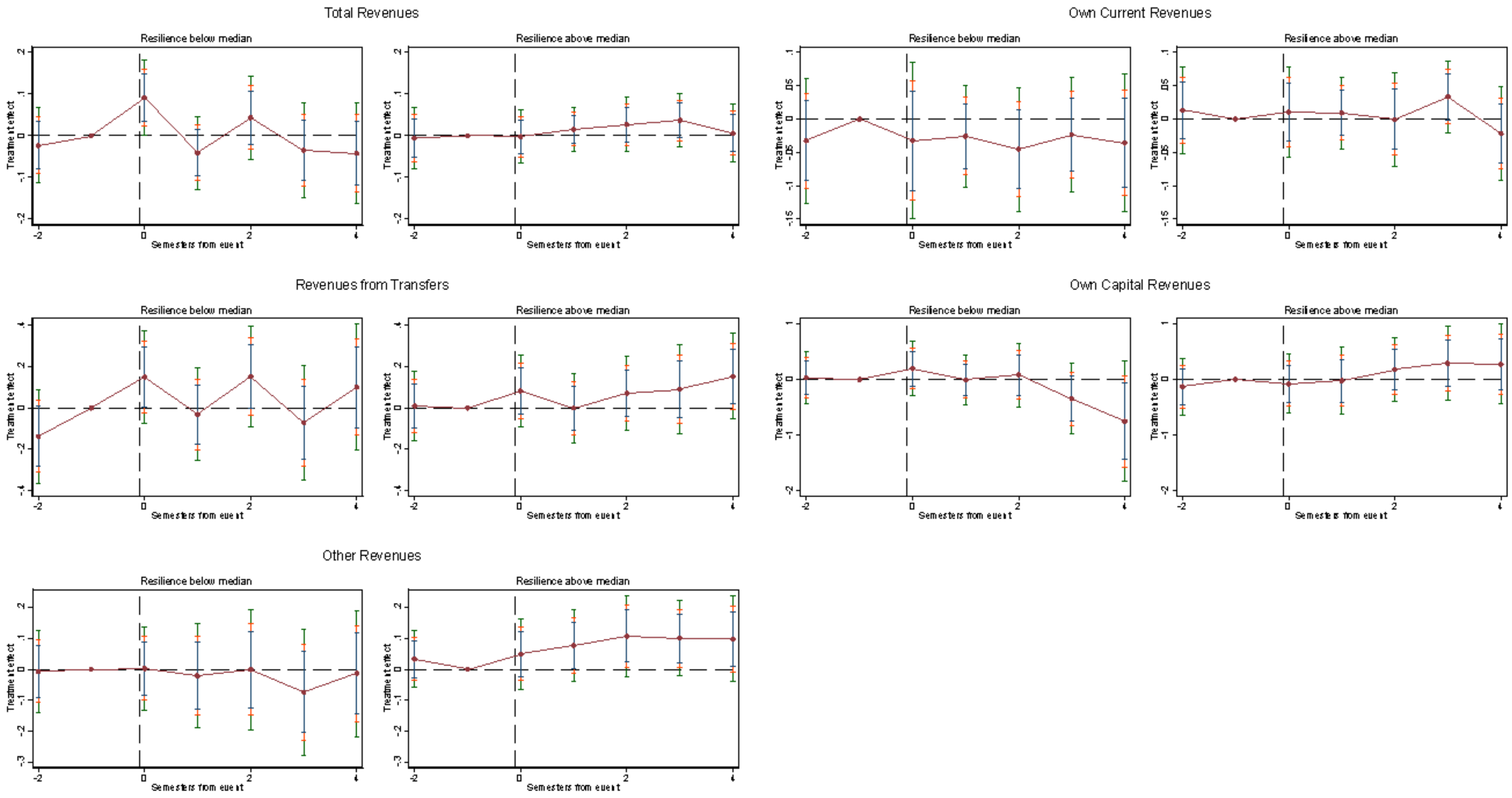
[15] ~~For what concerns "other~~"Other revenues~~", that~~," which are mainly connected to revenues from services provided on behalf of third parties, ~~they~~ appear to be positively affected by a flood in highly resilient municipalities.

Figure 5. Difference-in-differences Estimations by Resilience Level: Expenditures



Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

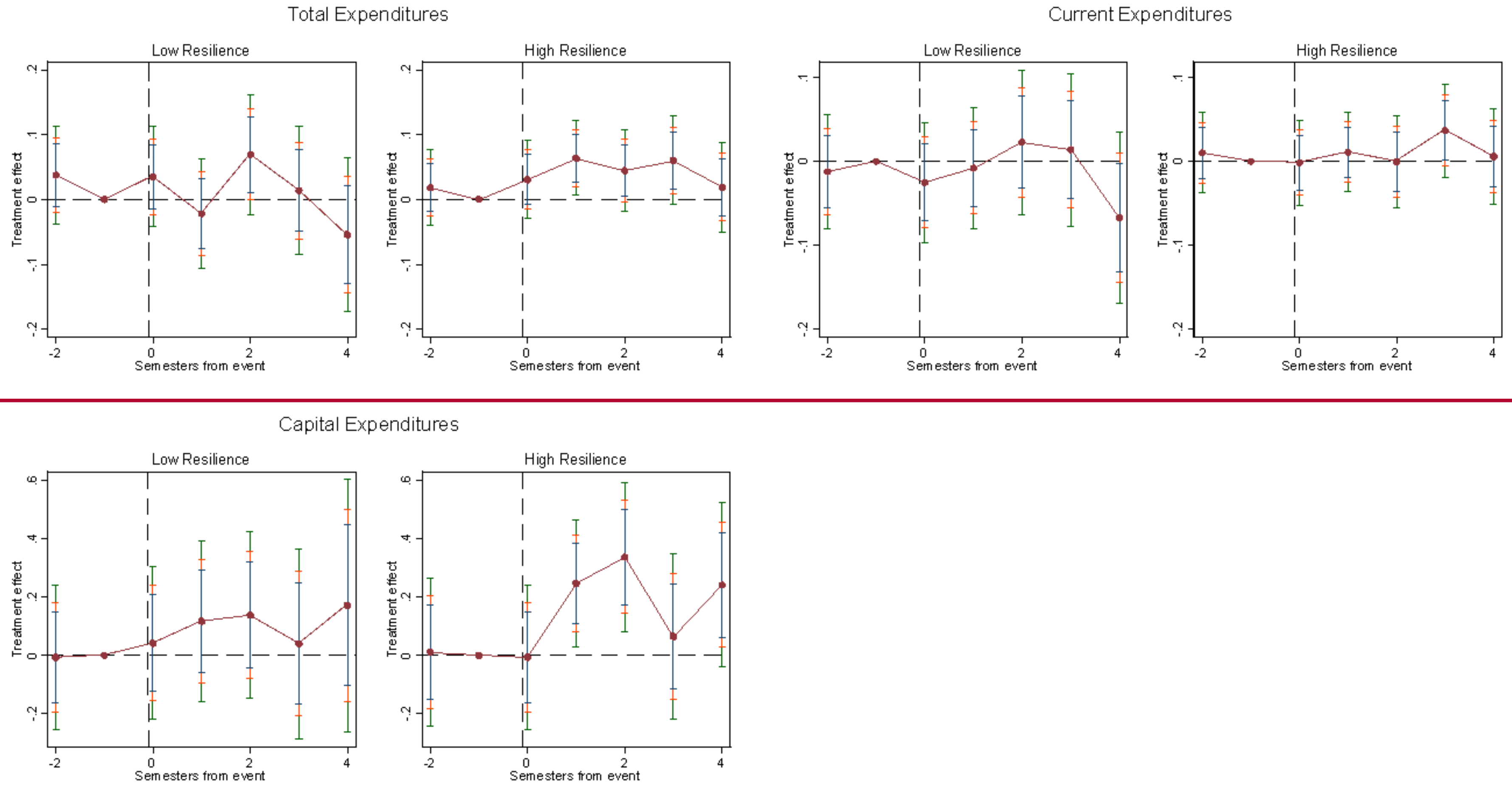
Figure 6. Difference-in-differences Estimations by Resilience Level: Revenues



Note: Three levels of statistical significance are reported: p-value < 0.1 (blue), p-value < 0.05 (orange), and p-value < 0.01 (green).

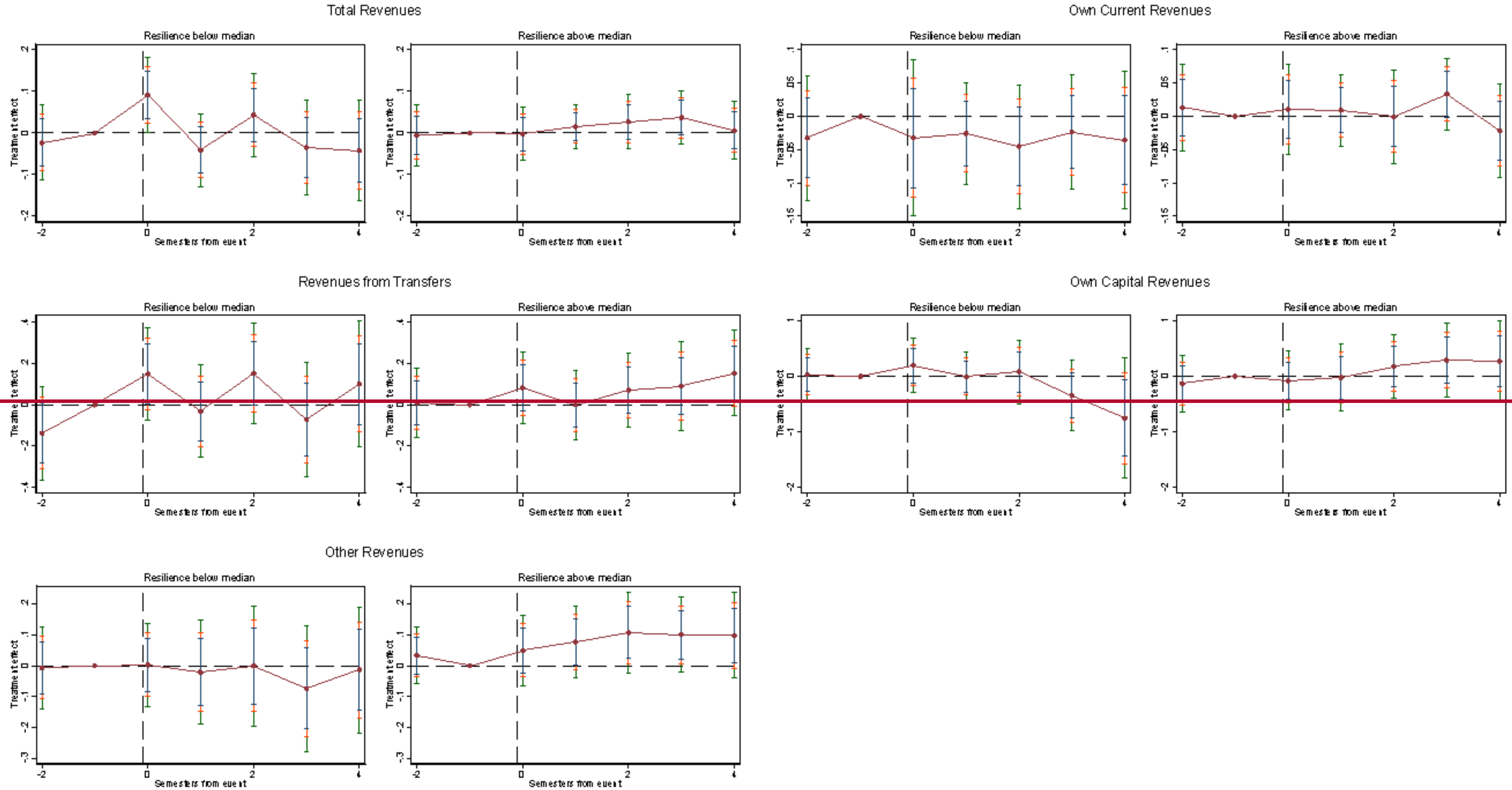
Our results suggest that other national or subnational governments (e.g~~.~~., NUTS2 regions) immediately transfer funds to support less resilient municipalities~~. However, it seems like~~ and that these transfers are not effectively used by local ~~governments of municipalities~~authorities with poor resilience. At the same time, highly resilient municipalities promptly respond to a flood by boosting capital expenditures, even without any significant transfer of resources from other levels of government.

~~Figure 5. Difference-in-Difference estimations by resilience level – Expenditures~~



~~Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.~~

~~Figure 6. Difference-in-Difference estimations by resilience level – Revenues~~



~~Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.~~

~~4.3~~5.3 *Heterogeneous effects: high- vs~~.~~ low~~-~~-vulnerability municipalities*

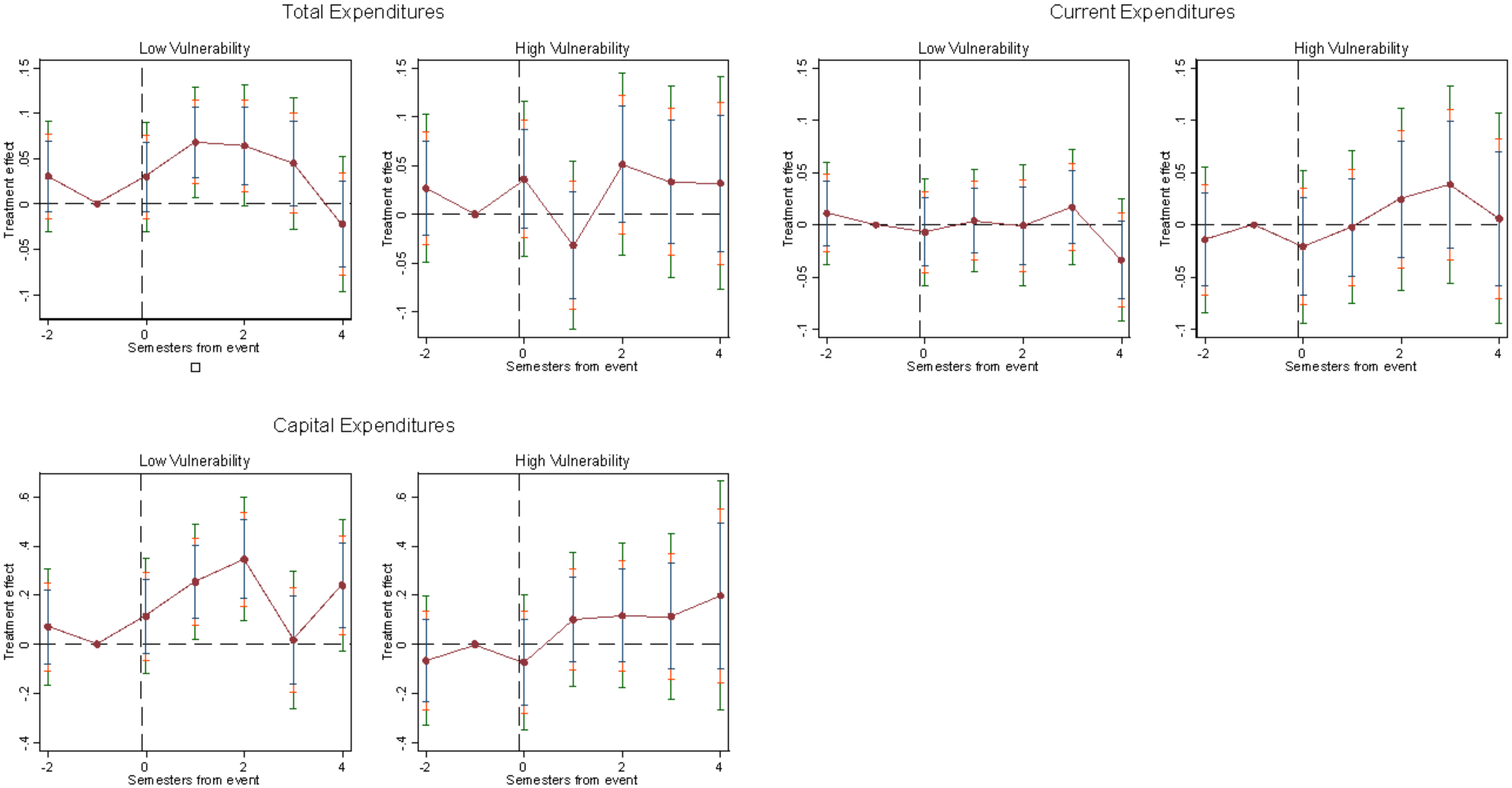
~~In order to~~

To corroborate our results on resilience, we replicate our analysis by looking at the vulnerability of municipalities. As mentioned before, resilience and vulnerability are strongly negatively correlated (correlation coefficient of -0.77). ~~However, in~~From our perspective, resilience and vulnerability~~, even if they~~ share some common characteristics~~,~~ but are two separate concepts that ~~are able to~~ capture ~~socio-economic~~socioeconomic differences ~~between~~among municipalities. This is reflected in the composition of the two indicators of resilience and vulnerability. Roughly speaking, we ~~can affirm~~suggest that resilience~~, in this context,~~ is ~~able to capture~~ the capacity of a municipality to ~~avoid that the~~prevent damages ~~will be 'embedded' into~~ from becoming embedded in the economic system ~~by shifting~~through a slowing down ~~the~~of economic growth~~ trajectory~~, while vulnerability is related to the capacity ~~of the municipalities~~ to suffer ~~socio-economic~~socioeconomic losses.

Figure 7 ~~reports~~shows the differential effects broken down by the level of vulnerability for expenditures. As expected, these results ~~for expenditure, broken down by level of vulnerability,~~ mirror ~~the ones~~those broken down by resilience (Figures 5 and 6). We estimate a substantial increase ~~of~~in total expenditures, driven by capital expenditures, in the aftermath of a flood (compared to the counterfactual) for municipalities with a low level of vulnerability. ~~On the other hand, no~~No significant effect is found for current expenditures~~,~~ nor for high- or low~~-~~-vulnerability municipalities.

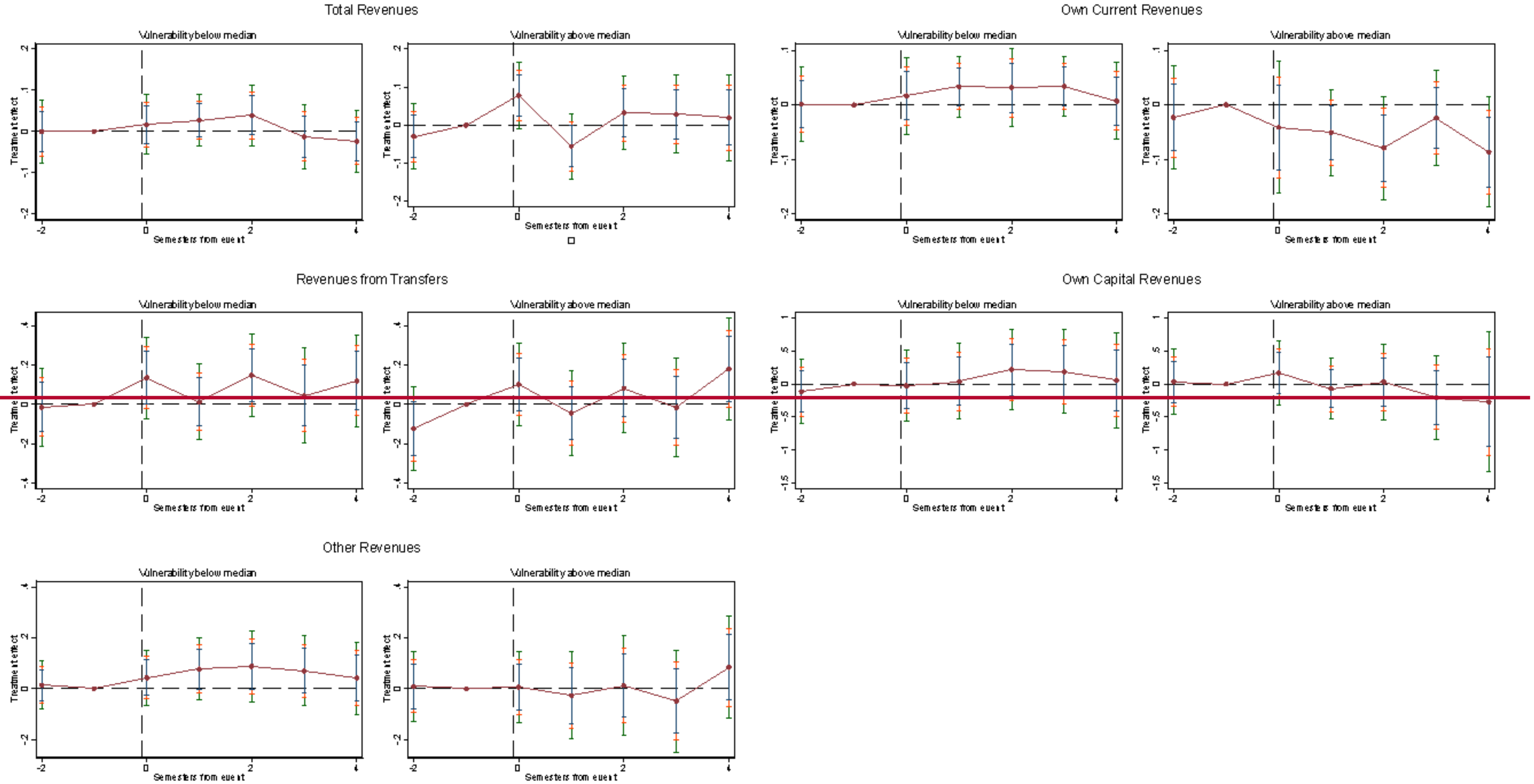
Focusing on revenues~~-side~~ (Figure 8), by comparing less vulnerable treated municipalities with the corresponding counterfactual, ~~they~~we can see that the former experienced an increase in total revenues until the second semester ~~post~~after the event semester and then ~~they started to~~a decrease. We do find some ~~specificities~~peculiarities when considering vulnerability instead of resilience. In the aftermath of the flood, more vulnerable municipalities show an increase in revenues (not entirely explained by an increase in transfers, which is not statistically different from zero), while less vulnerable ones experience an increase in transfers. We also observe a negative and significant post-flood effect on own current revenues for more vulnerable municipalities~~ and~~; this might ~~be the sign of~~signal a higher impact of the ~~flooding~~flood in more vulnerable municipalities ~~by shrinking the~~ in terms of a reduced tax base (e.g~~.~~., because of a reduction in the number of economic actors ~~present~~ in the ~~territories~~locale and/or prolonged tax cuts or exemptions).

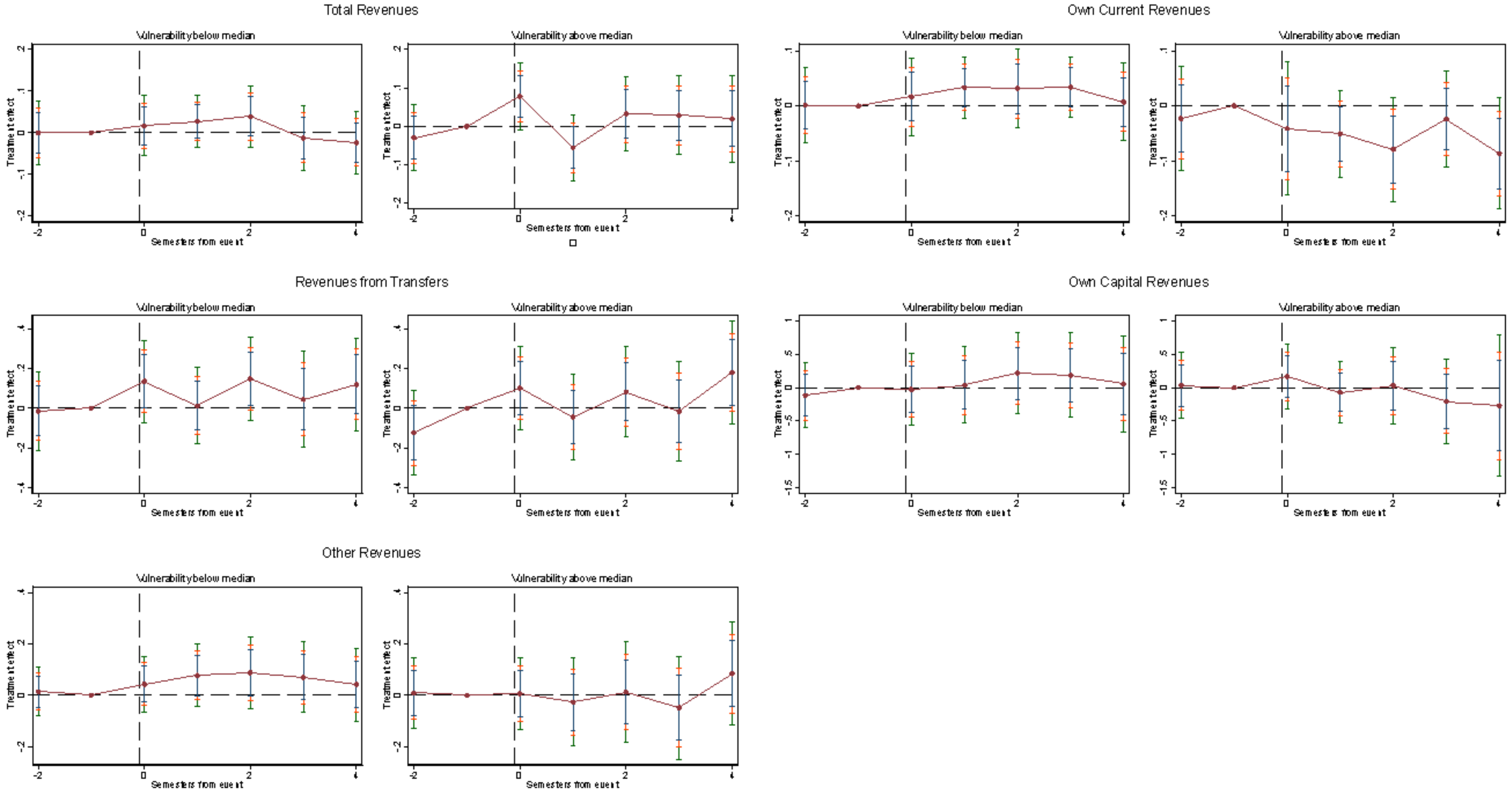
Figure 7. Estimations by ~~vulnerability level -~~Vulnerability Level: Expenditures



~~Notes: three~~Note: Three levels of statistical significance are reported~~. Blue~~: p-value~~<~~ < 0.1~~; Orange~~ (blue), p-value~~<~~ < 0.05~~; Green~~ (orange), and p-value~~<~~ < 0.01~~.~~ (green).

Figure 8. Estimations by ~~vulnerability level –~~ Vulnerability Level: Revenues


Total Revenues
Own Current Revenues
Revenues from Transfers
Own Capital Revenues
Other Revenues
Vulnerability below median
Vulnerability above median
Treatment effect
Semesters from event



Notes: ~~three~~Three levels of statistical significance are reported~~. Blue:~~ p-value~~<~~ < 0.1~~; Orange~~ (blue), p-value~~<~~ < 0.05~~; Green~~ (orange), and p-value~~<~~ < 0.01~~.~~ (green).

~~5~~6 Conclusions

~~Starting with the observation~~Observing that a growing number of floods have affected Italy in ~~the~~ recent decades and considering their impact on local economies, in this ~~paper~~article we ~~have~~ investigated the effect of ~~floods~~flooding on the short-term budgetary choices of local (municipal) governments, focusing on 4,185 ~~flooded~~ municipalities in ~~9~~nine Italian regions over the 2013~~-~~–2016 period. We ~~have developed~~used a dynamic difference-in-differences model with an a priori identification of proper counterfactuals through ~~a~~ propensity score matching ~~framework~~.

On average, ~~we estimate that~~ Italian ~~flooded~~ municipalities respond to ~~extreme~~flooding events by fostering public investments~~ and~~; this expenditure ~~increase~~growth is partly financed by increased transfers from other levels of government. This result highlights the ~~ability~~capability of municipalities to cope with floods and ~~to~~ react by boosting ~~the~~ post-flood recovery. Moreover, the ~~considered~~ floods ~~did~~in question do not affect the tax base, and the municipalities ~~did~~do not change local tax rates. A system that is fully funded through taxation represents a sort of “bet with nature” that incentivises bad government behaviour, as taxation is seen as cost-neutral with respect to spending in loss prevention. As a result, governments forego prevention and mitigation activities (Modica et al., 2019a). Still, other ways of funding or financing sources aimed at meeting additional allocations might depend on the peculiar characteristics of the affected individuals and territories.

We ~~then extend~~extended our analysis to ~~considering~~ heterogeneous effects based on the ex~~-~~-ante resilience and vulnerability of ~~affected~~the municipalities~~. It seems evident~~ in question. The results show that more resilient and less vulnerable municipalities can cope with unforeseen events because they ~~have a better capacity to use~~can invest available internal budgetary resources. These municipalities do not have to wait for external aid. Less resilient and more vulnerable municipalities highly depend on transfers from other national and subnational ~~governments.~~ levels of government.

Our ~~results bear~~findings have interesting policy implications~~, for instance they might~~. They can support policymakers ~~that aim to draw~~in planning general disaster management ~~but also~~as well as the relationship between national and local ~~governments~~levels of government in ~~the disasters~~disaster and ~~(eventual)~~ reconstruction management. For instance, Italy is ~~nowadays~~currently discussing ~~the~~a draft law ~~for~~on the adoption of a ~~"~~"Code of ~~reconstruction" and we~~Reconstruction. We believe that our results ~~might be~~could make a pivotal contribution to this debate for at least two reasons.

First, as ~~local governments~~municipalities respond to floods by increasing their capital investments without an adjustment of their ~~own~~ revenues, substantial imbalances can be generated in their ~~accounts.~~financial budgets. This ~~result~~finding points to the need to grant some degree of flexibility to incur ~~in~~ deficits in the aftermath of a disaster. Second, the prompt response in terms of increased capital expenditures appears to be larger for more resilient and less vulnerable municipalities. ~~*Ex*~~ Therefore, the ex-ante capacity to cope with extreme events and ~~to~~ limit ~~the~~ damages is a good predictor of ~~municipality~~a municipality's post-disaster recovery ~~ability~~capability. In this respect, the implication is not straightforward. On ~~the~~ one hand, the long-term strategy for local and regional-national governments should be to enhance the resilience of municipalities and ~~to~~ reduce their vulnerability. On the other hand, in the short term, there is room for ~~a~~ direct intervention ~~of~~by the regional or national ~~governments~~government in terms of direct capital spending in flooded, less resilient and more vulnerable areas. ~~Linked to this~~Relatedly, our ~~results~~findings highlight that the transfer of funds to local governments in less resilient and more vulnerable municipalities is not enough to boost local capital expenditures. This ~~points to the fact~~means that the failure to increase capital expenditures in these municipalities does not depend on tight financial or regulatory constraints but on the inability to operationalise additional spending in the short ~~run.~~ term.

This ~~work~~article can represent a starting point for future research. ~~For instance, it~~It would be ~~of particular interest~~very interesting to consider the political ~~economy~~-economic mechanisms behind a municipality's budgetary dynamics by examining, for example ~~accounting for~~, a mayor's characteristics and ~~for~~ the electoral cycle. ~~It can be also possible to apply the same~~ Furthermore, the econometric approach used here could be employed to estimate the ~~effect~~effects of other extreme natural events, such as earthquakes, ~~that~~which also strongly affect the Italian peninsula ~~too. Furthermore~~. Finally, a similar approach ~~can~~could be applied to the private sector (i.e., firms) to investigate if it ~~analogously~~ responds to extreme events~~.~~

in the same way as the public sector.

References

Amadio, M., Scorzini, A. R., Carisi, F., Essenfelder, A. H., Domeneghetti, A., Mysiak, J., Castellarin, A. (2019). Testing empirical and synthetic flood damage models: the case of Italy. *Natural Hazards and Earth System Science*, 19, 661–678.

ANCE/CRESME (2012). Città mercato e rigenerazione 2012. Analisi del contesto per una nuova politica urbana, Roma.

Bachner, G., Bednar-Friedl, B. (2019). The effects of climate change impacts on public budgets and implications of fiscal counterbalancing instruments. *Environmental Modeling & Assessment*, 24(2), 121-142.

Bakar, A. C., Larcker, D. F., Wang, C. C. Y. (2020). How much should we trust staggered difference-in-differences estimates? *Journal of Financial Economics*, 144(2), 370-395.

Benson, C., Clay, E. (2004). Understanding the economic and financial impacts of natural disasters. *Disaster Risk Management Series* No. 4, The World Bank.

Breckner, M., Englmaier, F., Stowasser, T., Sunde, U. (2016). Resilience to natural disasters—Insurance penetration, institutions, and disaster types. *Economics Letters*, 148, 106-110.

Cannizzaro, S., De Pascale, F., Farabollini, P., Muto, F. (2020). Introduction to the Special Issue “Socio-Natural Disasters and Vulnerability Reduction in the territorial ecosystems”. *AIMS Geosciences*, 6, 1-5.

Chan, E. Y., Yue, J., Lee, P., Wang, S. S. (2016). Socio-demographic predictors for urban community disaster health risk perception and household based preparedness in a Chinese urban city. *PLoS currents*, 8.

CNI (2016). Accise e terremoti. CGIA Mestre, retrieved at http://www.cgiamestre.com/wp-content/uploads/2016/09/ACCISE-E-TERREMOTI.pdf

Cutter, S. L., Ash, K. D., Emrich, C. T. (2016). Urban–rural differences in disaster resilience. *Annals of the American Association of Geographers*, 106(6), 1236-1252.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, 18(4), 598-606.

Donnini, M., Modica, M., Salvati, P., Marchesini, I., Rossi, M., Guzzetti, F., Zoboli, R. (2020). Economic landslide susceptibility under a socio-economic perspective: an application to Umbria Region (Central Italy). *Review of Regional Research*, 40(2), 159-188.

EEA (2010). Mapping the impacts of natural hazards and technological accidents in Europe: An overview of the last decade. EEA Technical Report No 13. ISSN 1725-2237.

EEA (2016). Flood risks and environmental vulnerability – Exploring the synergies between floodplain restoration, water policies and thematic policies, https://doi.org/10.2800/039463.

Faiella, I., Natoli, F. (2018). Natural catastrophes and bank lending: the case of flood risk in Italy. *Bank of Italy Occasional Paper*, (457).

Franzi, L., Bianco, G., Bruno, A. Foglino, S. (2016). Flood Risk Assessment and Quantification in the Piedmont Region, Italy. In: Tiepolo M. "Planning to cope with tropical and subtropical climate change". De Gruyter Open Poland.

Hallegatte, S. (2014a). Natural Disasters and Climate Change. An Economic Perspective. Springer International Publishing Switzerland.

Hallegatte S. (2014b). Economic Resilience: definition and measurement. *World Bank Policy Research Working Paper* N. 6852.

Heipertz, M., Nickel, C. (2008). Climate Change Brings Stormy Days: Case Studies on the Impact of Extreme Weather Events on Public Finances. Available at SSRN: ~~or~~ https://ssrn.com/abstract=1997256

Holling, C. S., (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, 4, 1-23.

IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. IPCC Sixth Assessment Report, ISBN 978-92-9169-159-3.

ISPRA (2021). Rapporto sulle condizioni di pericolosità da alluvione in Italia e indicatori di rischio associati, N. 353. ISBN: 978-88-448-1080-1.

Jerch, R., Khan, M. E., Lin, G. C. (2021). Local public finance dynamics and hurricane shocks. *NBER Working Paper*~~.~~ No. 28050.

Kahn, M. E. (2005). The death toll from natural disasters: the role of income, geography, and institutions. *Review of Economics and Statistics*, 87(2), 271-284.

Khan, N.A., Gao, Q., Abid, M. (2020). Public institutions' capacities regarding climate change adaptation and risk management support in agriculture: the case of Punjab Province, Pakistan. *Scientific Report*, 10, 14111.

Kirchmeier-Young, M. C., Zhang, X. (2020). Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences*, 117(24), 13308-13313.

Lis, E. M., Nickel, C. (2010). The impact of extreme weather events on budget balances. *International Tax and Public Finance*, 17(4), 378-399.

Marin, G., Modica, M. Paleari, S., Zoboli, R. (2021). Assessing disaster risk by integrating natural and socio-economic dimensions: A decision-support tool. *Socio-Economic Planning Sciences*, 77, 101032.

Martin, R. (2012). Regional economic resilience, hysteresis and recessionary shocks. *Journal of Economic Geography*, 12 (1), 1–32.

Melecky, M., Raddatz, C. (2014). Fiscal Responses after catastrophes and the enabling role of financial development. *The World Bank Economic Review*~~.~~, 1-21.

Miao, Q., Hou, Y., Abrigo, M. (2018). Measuring the financial shock of natural disasters. A panel study of U.S states. *National Tax Journal*~~.~~, 71(1).

Miao, Q., Chen, C., Lu, Y., Abrigo, M. (2020). Natural disasters and financial implications for subnational governments: Evidence from China. *Public Finance Review*~~.~~, 48(1): 72-101.

Modica, M., Faggian, A., & Aloisio, R. (2019a). The Post-Earthquake Reconstruction in L'Aquila: Some Reflections. *Scienze Regionali*, 18(3), 515-522.

Modica M., Reggiani A., Nijkamp P. (~~2019~~2019b). Vulnerability, Resilience and Exposure: Methodological Aspects. In: Okuyama Y., Rose A. (eds) Advances in Spatial and Economic Modeling of Disaster Impacts. Advances in Spatial Science (The Regional Science Series). Springer, Cham.

Noy, I., Nualsri, A. (2011). Fiscal storms: public spending and revenues in the aftermath of natural disasters. *Environmental and Development Economics*, 16~~:~~, 113-128.

Ostadtaghizadeh, A., Ardalan, A., Paton, D., Khankeh, H., ~~-~~Jabbari, H. (2016). Community disaster resilience: a qualitative study on Iranian concepts and indicators. *Natural Hazards*, 83(3), 1843-1861.

Parsons, M., Glavac, S., Hastings, P., Marshall, G., McGregor, J., McNeill, J., Stayner, R. (2016). Top-down assessment of disaster resilience: A conceptual framework using coping and adaptive capacities. *International Journal of Disaster Risk Reduction*, 19, 1-11.

Phaup, M., Kirschner, C. (2010). Budgeting for disasters: focusing on the good times. *OECD Journal on Budgeting*, 10(1), 1-24.

Pimm, S. L. (1984). The complexity and stability of ecosystems. *Nature*, 307, 321–326.

Raschky, P. A. (2008). Institutions and the losses from natural disasters. *Natural Hazards and Earth System Sciences*, 8(4), 627-634.

Rose, A. (2004). Defining and measuring economic resilience to disasters. *Disaster Prevention and Management*, 13 (4), 307-314.

Sarewitz D., Pielke R., Keykhah M. (2003). Vulnerability and risk: some thoughts from a political and policy perspective. *Risk Analysis*, 23(4), 805–10.

Taulbee, L. (2019). The Local Government Financial Response to Natural Disasters in Kentucky. MPA/MPP Capstone Projects, 330.

UNISDR (2009). UNISDR Terminology and Disaster Risk Reduction. UNISDR, Geneva, Switzerland.

WMO (2021). WMO atlas of mortality and economic losses from weather, climate and water extremes (1970–2019). World Meteorological Organization, Geneva, Switzerland, ISBN: 978-92-63-11267-5

Zampetti, G., Ottaviani, F., Minutolo, A. (2012). I costi del rischio idrogeologico, Dossier Legambiente, Roma, 2012.

Zhou, L. and Chen, Z. (2020). Are CGE models reliable for disaster impact analyses? *Economic Systems Research*, 20-4.

Appendix A - Outcomes Variables, Vulnerability and Resilience Index Description

Table A.1 Outcomes description

Variable	Description
Total Expenditures	Total monthly expenditures
Current Expenditures	Monthly current expenditures (personnel, raw materials and consumables procurement, service provisions, use of third-party assets, current transfers, interests and financial charges, taxes and fees, extraordinary charges from current operations, loan repayment charges, expenses from services on behalf of third parties, payment to be settled).
Capital Expenditures	Monthly capital expenditures (real estate acquisition, expropriations and onerous easements, purchase of specific good for in-house production, use of third-party assets for economic activities, Acquisition of furniture, machinery and technical and scientific equipment, external professional appointments, capital transfers, shareholdings, capital contributions, granting of loans and advances).
Total Revenues	Total monthly revenues.
Own Current Revenues	Monthly current revenues (taxes and fees, public services revenues, income from the assets of the municipality, interests on advances and loans, net profits of special and participates companies, dividends of companies).
Own Capital Revenues	Monthly capital revenues (disposal of assets, debt collection, cash advances, short term loans, borrowing and lending, issuance of bonds).
Revenues from Transfers	Monthly revenues from transfers (capital transfers from state, regions, autonomous provinces, public sector, other subjects).
Other Revenues	Monthly other revenues (social security and welfare deductions for staff, withholding taxes, other deductions from staff on behalf of third parties, security deposits, reimbursement of expenses for services on behalf of third-party, repayment of advance payment of funds for the treasury service, deposits for contractual expenses, collections to be regularised).

Table A.2 The components of the vulnerability index

	Vulnerability	Note	Sign
1	Extension of agriculture	Percentage of agricultural land	+
2	Dependency on agriculture	Number of cattle per person	+
3	Age	Dependency ratio	+
4	Wealth	Average income per household	-
5	Poverty	Households with potential economic discomfort	+
6	Inequality	Gini Index	+
7	Unemployment	Unemployment rate	+
8	Institutional capacity	Synthetic index defined as the simple average of employees in different branch of PA	-
9	Political rights	Turnover of 2014 EU Parliament election	-
10	Population pressure	Population density	+

11	Urbanisation	Land use per capita	+
12	Building characteristics	Herfindahl-Hirschman index for residential, non-residential buildings (functional mix)	+
13	Ecosystem conversion	% of agricultural area actually used (SAU) on total agricultural area	+
14	Education	Ratio between people in the age 15-24 who does not attend a regular course of study and population of 15-24 years	+
15	Family structure	Ratio between the number of single-parent households over total number of households	+
16	Female condition	Male employment rate over female employment rate	+
17	Health	Hospital beds for 10,000 inhabitants	-

Source: Marin et al. (2021)

Table A.3 - The components of the resilience index

	Resilience	Note	Sign
1	Density of business	Number of local units per km2	+
2	Wealth	Average income per household	+
3	Debt	Debt of the public administration per capita	-
4	Poverty	Households with potential economic discomfort	-
5	Homeownership	Affordability index	+
6	Unemployment	Unemployment rate	-
7	Productivity	Sales per employee	+
8	Sectorial dependence	Herfindahl-Hirschman concentration index of employees in the economic sectors	-
9	Government effectiveness	Paid expenditure / Committed expenditure of municipal governments	+
10	Institutional capacity	Synthetic index defined as the simple average of employees in different branch of PA	+
11	Education	Ratio between resident in the age 15-24 who does not attend a regular course of study and resident population of 15-24 years	+
12	Health	Hospital beds for 10,000 inhabitants	+
13	Social capital	Synthetic index defined as the simple average of normalized scores of No. and employees of non-profit association; Blood donations; No. of non-sport newspapers sold/1000 person; tolerance and trust question in the WVS	+

Source: Marin et al. (2021)

Appendix B – Balancing test of matching based on propensity score and difference-in-difference estimates tables

Table B.1.1. Balancing test of matching based on propensity score – Unmatched

	Population	Income	Area	Altitude	Island	Coastal	Hazard	Resilience	Vulnerability
Control	7.969	17.25	2.839	5.012	0.005	0.113	0.072	0.517	0.517
Treated	8.059	17.34	3.223	4.734	0.006	0.182	0.077	0.445	0.468
Difference	0.090	0.086	0.385	-0.278	0.001	0.069	0.006	-0.073	-0.050
t-stat	2.030**	1.740*	12.13***	-4.491***	0.502	4.944***	1.090	-4.070***	-2.768***
N. obs.	52865	51245	51121	51076	51121	51121	51121	52870	52870

Table B.1.2. Balancing test of matching based on propensity score - Matched

Outcome: ***Total Expenditure***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.007	17.28	3.161	4.903	0.006	0.0974	0.157	0.064
Treated	8.047	17.32	3.154	4.862	0.004	0.0875	0.125	0.062
Difference	0.040	0.033	-0.006	-0.041	-0.002	-0.010	-0.032	-0.002
t_Stat	0.558	0.412	-0.121	-0.383	-0.501	-0.570	-1.699*	-0.214
N. Observations				1319				
Outcome: ***Current Expenditure***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.031	17.31	3.191	4.791	0.007	0.100	0.094	0.065
Treated	8.050	17.32	3.154	4.830	0.004	0.087	0.086	0.064
Difference	0.019	0.013	-0.037	0.040	-0.003	-0.014	-0.008	-0.002
t-stat	0.260	0.169	-0.718	0.364	-0.656	-0.774	-0.528	-0.260
N. Observations				1315				
Outcome ***Capital Expenditure***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.020	17.30	3.184	4.815	0.002	0.090	0.309	0.080
Treated	8.069	17.34	3.151	4.823	0.004	0.094	0.287	0.065
Difference	0.048	0.043	-0.033	0.008	0.002	0.004	-0.022	-0.016
t-stat	0.669	0.546	-0.649	0.077	0.633	0.228	-0.321	-1.905
N. Observations				1316				
Outcome: ***Total revenues***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.070	17.35	3.134	4.808	0.005	0.103	0.257	0.072
Treated	8.050	17.32	3.149	4.845	0.004	0.0895	0.265	0.063
Difference	-0.020	-0.036	0.015	0.037	-0.001	-0.014	0.008	-0.008
t-stat	-0.279	-0.458	0.291	0.343	-0.259	-0.776	0.330	-1.104
N. Observations				1300				
Outcome: ***Own current revenues***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.048	17.33	3.170	4.882	0.006	0.102	0.225	0.060
Treated	8.063	17.33	3.159	4.841	0.004	0.089	0.236	0.064
Difference	0.014	0.004	-0.011	-0.040	-0.002	-0.013	0.011	0.004
t-stat	0.197	0.0453	-0.208	-0.371	-0.472	-0.711	0.448	0.554
N. Observations				1322				
Outcome: ***Revenues from transfers***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.065	17.34	3.136	4.826	0.006	0.087	0.384	0.067
Treated	8.045	17.31	3.146	4.846	0.004	0.083	0.438	0.060

Difference	-0.020	-0.030	0.010	0.020	-0.002	-0.004	0.055	-0.006
t-stat	-0.284	-0.388	0.185	0.180	-0.472	-0.232	0.854	-0.857
N. Observations				1281				

Outcome: ***Capital Revenues***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.089	17.34	3.179	4.872	0.003	0.081	-0.038	0.068
Treated	8.174	17.42	3.225	4.780	0.006	0.097	0.047	0.071
Difference	0.085	0.083	0.046	-0.092	0.003	0.016	0.085	0.002
t-stat	1.036	0.909	0.768	-0.692	0.633	0.736	0.631	0.262
N. Observations				914				

Outcome: ***Other Revenues***	Population	Income	Area	Altitude	Island	Coastal	Pre-Trend	Hazard
Control	8.014	17.29	3.148	4.878	0.004	0.110	0.177	0.056
Treated	8.051	17.32	3.147	4.837	0.004	0.093	0.153	0.062
Difference	0.037	0.029	-0.001	-0.041	-0.000	-0.017	-0.024	0.006
t-stat	0.510	0.362	-0.027	-0.378	-0.000	-0.889	-0.787	0.900
N. Observations				1317				

Table B.2. Baseline Estimations - Expenditures

Treatment Effect	Total Expenditures	Current Expenditures	Capital Expenditures
1st Semester (pre)	0.029	-0.002	0.001
	(0.019)	(0.016)	(0.069)
Semester of the event	0.033*	-0.014	0.019
	(0.019)	(0.017)	(0.070)
1st Semester (post)	0.018	0.001	0.177**
	(0.021)	(0.0171)	(0.070)
2nd Semester (post)	0.058***	0.012	0.231***
	(0.022)	(0.020)	(0.075)
3rd Semester (post)	0.038*	0.026	0.048
	(0.023)	(0.020)	(0.084)
4th Semester (post)	-0.008	-0.021	0.206**
	(0.024)	(0.021)	(0.092)
N. Observations	8496	8481	8453

Notes: Fixed effect model. Standard errors clustered by municipalities in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table B.3. Baseline Estimations – Revenues

Treatment Effect	Total Revenues	Current Revenues	Revenues from Transfers	Capital Revenues	Other Revenues
1st Semester (pre)	-0.015	-0.011	-0.069	-0.035	0.012
	(0.023)	(0.023)	(0.057)	(0.137)	(0.032)
Semester of the event	0.048**	-0.012	0.119**	0.074	0.024
	(0.022)	(0.027)	(0.057)	(0.139)	(0.035)
1st Semester (post)	-0.014	-0.009	-0.017	-0.018	0.025
	(0.021)	(0.019)	(0.056)	(0.140)	(0.041)
2nd Semester (post)	0.036	-0.024	0.115*	0.124	0.050
	(0.024)	(0.023)	(0.060)	(0.162)	(0.047)
3rd Semester (post)	0.004	0.005	0.015	-0.006	0.016
	(0.025)	(0.020)	(0.068)	(0.176)	(0.046)
4th Semester (post)	-0.010	-0.033	0.131*	-0.059	0.047
	(0.025)	(0.023)	(0.068)	(0.229)	(0.046)
N. Observations	8370	8514	8261	5194	8481

Notes: Fixed effect model. Standard errors clustered by municipalities in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table B.4. Estimations by resilience level - Expenditures

	Below Median	*Above Median*

Treatment Effect	Total Expenditures	Current Expenditures	Capital Expenditures	Total Expenditures	Current Expenditures	Capital Expenditures
1st Semester (pre)	0.038	-0.012	-0.007	0.018	0.010	0.011
	(0.029)	(0.027)	(0.095)	(0.023)	(0.019)	(0.099)
Semester of the event	0.035	-0.025	0.042	0.030	-0.002	-0.007
	(0.030)	(0.028)	(0.102)	(0.023)	(0.020)	(0.095)
1st Semester (post)	-0.022	-0.008	0.117	0.064***	0.011	0.247***
	(0.033)	(0.028)	(0.108)	(0.022)	(0.018)	(0.084)
2nd Semester (post)	0.069*	0.023	0.138	0.044*	-0.001	0.338***
	(0.036)	(0.033)	(0.111)	(0.025)	(0.021)	(0.099)
3rd Semester (post)	0.014	0.014	0.040	0.060**	0.037*	0.065
	(0.038)	(0.035)	(0.126)	(0.026)	(0.022)	(0.110)
4th Semester (post)	-0.054	-0.067*	0.171	0.019	0.006	0.242**
	(0.046)	(0.040)	(0.168)	(0.027)	(0.022)	(0.109)
N. Observations	4291	4168	4278	4205	4313	4175

Notes: Fixed effect model. Standard errors clustered by municipalities in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table B.5. Estimations by vulnerability level - Expenditures

	Below Median			*Above Median*		
Treatment Effect	Total Expenditures	Current Expenditures	Capital Expenditures	Total Expenditures	Current Expenditures	Capital Expenditures
1st Semester (pre)	0.031	0.011	0.070	0.027	-0.014	-0.067
	(0.024)	(0.019)	(0.092)	(0.029)	(0.027)	(0.102)
Semester of the event	0.030	-0.007	0.113	0.036	-0.021	-0.074
	(0.023)	(0.020)	(0.091)	(0.031)	(0.028)	(0.107)
1st Semester (post)	0.068***	0.004	0.253***	-0.032	-0.002	0.101
	(0.024)	(0.019)	(0.091)	(0.033)	(0.028)	(0.105)
2nd Semester (post)	0.064**	-0.001	0.346***	0.051	0.024	0.117
	(0.026)	(0.022)	(0.098)	(0.036)	(0.034)	(0.114)
3rd Semester (post)	0.045	0.017	0.018	0.033	0.039	0.114
	(0.028)	(0.021)	(0.109)	(0.038)	(0.037)	(0.131)
4th Semester (post)	-0.022	-0.034	0.239**	0.032	0.006	0.198
	(0.029)	(0.023)	(0.103)	(0.042)	(0.039)	(0.181)
N. Observations	4551	4480	4534	3945	4001	3919

Notes: Fixed effect model. Standard errors clustered by municipalities in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table B.6. Estimations by resilience level - Revenues

	Below Median					*Above Median*				
Treatment Effect	Total Revenues	Current Revenues	Revenues from Transfers	Capital Revenues	Other Revenues	Total Revenues	Current Revenues	Revenues from Transfers	Capital Revenues	Other Revenues
1st Semester (pre)	-0.023	-0.032	-0.138	0.029	-0.007	-0.0056	0.013	0.010	-0.129	0.033
	(0.035)	(0.037)	(0.089)	(0.183)	(0.052)	(0.029)	(0.026)	(0.066)	(0.199)	(0.036)
Semester of the event	0.092***	-0.032	0.150*	0.194	0.003	-0.002	0.010	0.083	-0.082	0.049
	(0.035)	(0.046)	(0.088)	(0.189)	(0.053)	(0.025)	(0.026)	(0.068)	(0.206)	(0.044)
1st Semester (post)	-0.041	-0.026	-0.031	-0.010	-0.021	0.016	0.009	-0.000	-0.025	0.077*
	(0.034)	(0.030)	(0.088)	(0.170)	(0.066)	(0.020)	(0.021)	(0.065)	(0.233)	(0.045)
2nd Semester (post)	0.043	-0.045	0.153	0.079	-0.001	0.027	-0.000	0.071	0.177	0.108**
	(0.039)	(0.036)	(0.095)	(0.223)	(0.075)	(0.025)	(0.027)	(0.069)	(0.226)	(0.051)
3rd Semester (post)	-0.035	-0.023	-0.072	-0.348	-0.075	0.037	0.033	0.090	0.292	0.101**
	(0.044)	(0.033)	(0.109)	(0.244)	(0.080)	(0.025)	(0.021)	(0.084)	(0.255)	(0.048)
4th Semester (post)	-0.042	-0.036	0.101	-0.753*	-0.014	0.006	-0.022	0.153*	0.274	0.098*
	(0.047)	(0.040)	(0.119)	(0.420)	(0.079)	(0.027)	(0.027)	(0.081)	(0.278)	(0.054)
N. Observations	4253	4308	4087	2751	4240	4117	4206	4174	2443	4241

Notes: Fixed effect model. Standard errors clustered by municipalities in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table B.7. Estimations by vulnerability level - Revenues

	Below Median					*Above Median*				
Treatment Effect	Total Revenues	Current Revenues	Revenues from Transfers	Capital Revenues	Other Revenues	Total Revenues	Current Revenues	Revenues from Transfers	Capital Revenues	Other Revenues
1st Semester (pre)	-0.000	0.001	-0.0135	-0.117	0.014	-0.030	-0.023	-0.124	0.033	0.010
	(0.030)	(0.026)	(0.076)	(0.189)	(0.037)	(0.034)	(0.037)	(0.083)	(0.192)	(0.053)
Semester of the event	0.017	0.017	0.136*	-0.026	0.043	0.078**	-0.041	0.102	0.167	0.006

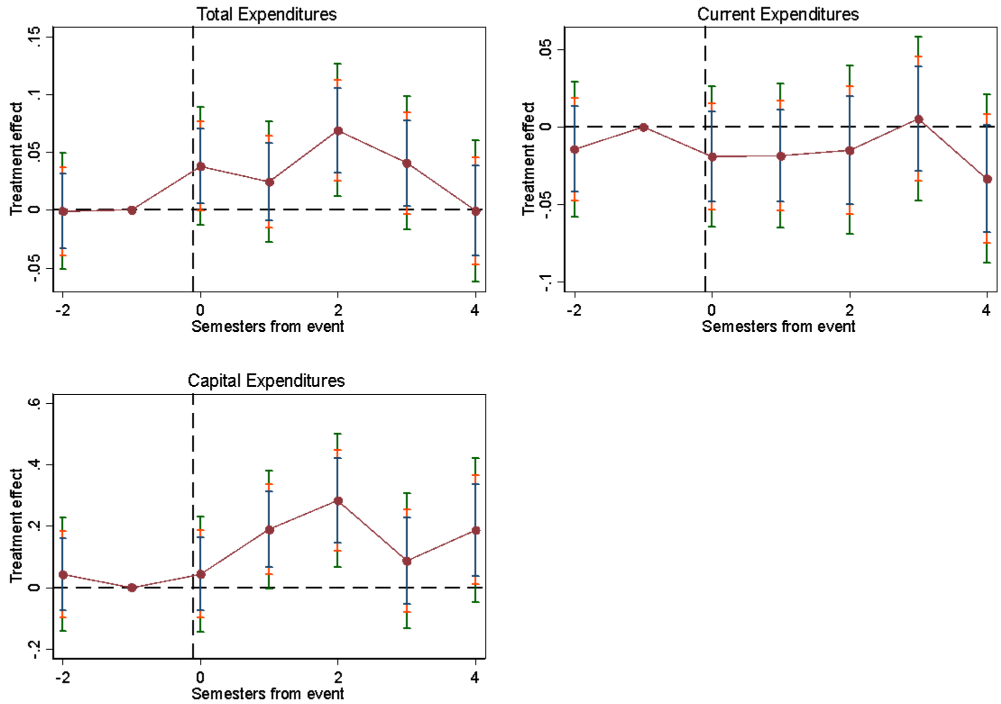
	(0.028)	(0.027)	(0.081)	(0.209)	(0.043)	(0.034)	(0.047)	(0.081)	(0.186)	(0.055)
1st Semester (post)	0.028	0.033	0.012	0.038	0.077	-0.055*	-0.051*	-0.044	-0.069	-0.027
	(0.024)	(0.021)	(0.075)	(0.222)	(0.048)	(0.033)	(0.030)	(0.083)	(0.177)	(0.066)
2nd Semester (post)	0.039	0.031	0.149*	0.217	0.088	0.032	-0.079**	0.082	0.029	0.013
	(0.029)	(0.027)	(0.082)	(0.237)	(0.055)	(0.038)	(0.037)	(0.088)	(0.221)	(0.076)
3rd Semester (post)	-0.012	0.034	0.045	0.185	0.070	0.029	-0.024	-0.016	-0.206	-0.048
	(0.030)	(0.021)	(0.094)	(0.246)	(0.053)	(0.040)	(0.034)	(0.097)	(0.248)	(0.078)
4th Semester (post)	-0.023	0.007	0.121	0.056	0.042	0.020	-0.086**	0.180*	-0.272	0.084
	(0.029)	(0.027)	(0.091)	(0.279)	(0.055)	(0.044)	(0.039)	(0.101)	(0.412)	(0.078)
N. Observations	4436	4501	4410	2548	4458	3934	4013	3851	2646	4023

Notes: Fixed effect model. Standard errors clustered by municipalities in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Appendix C – Robustness checks

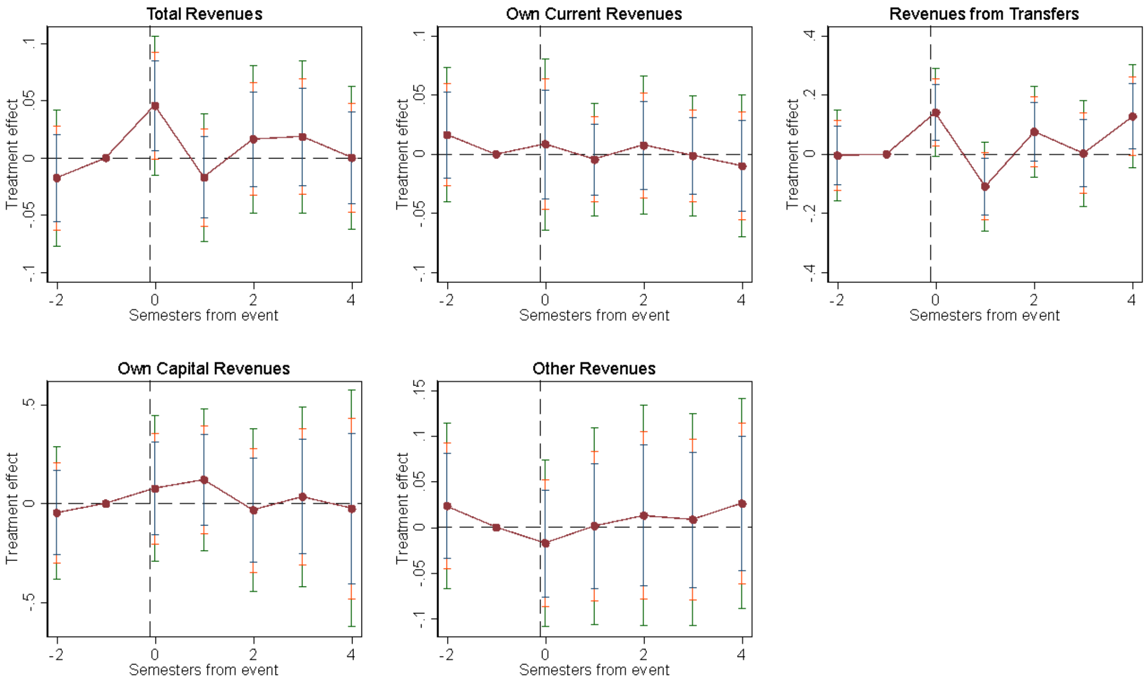
In order to check the robustness of our analysis, we have estimated the municipalities budgetary outcomes by applying a propensity score matching where municipalities are matched by considering the exact value of their level of resilience and the quartile of their 6-month pre-trend. Obtained results are reported from Figure B.1 to B.6 and are robust.

Figure C.1. Difference-in-differences baseline estimations - Expenditures



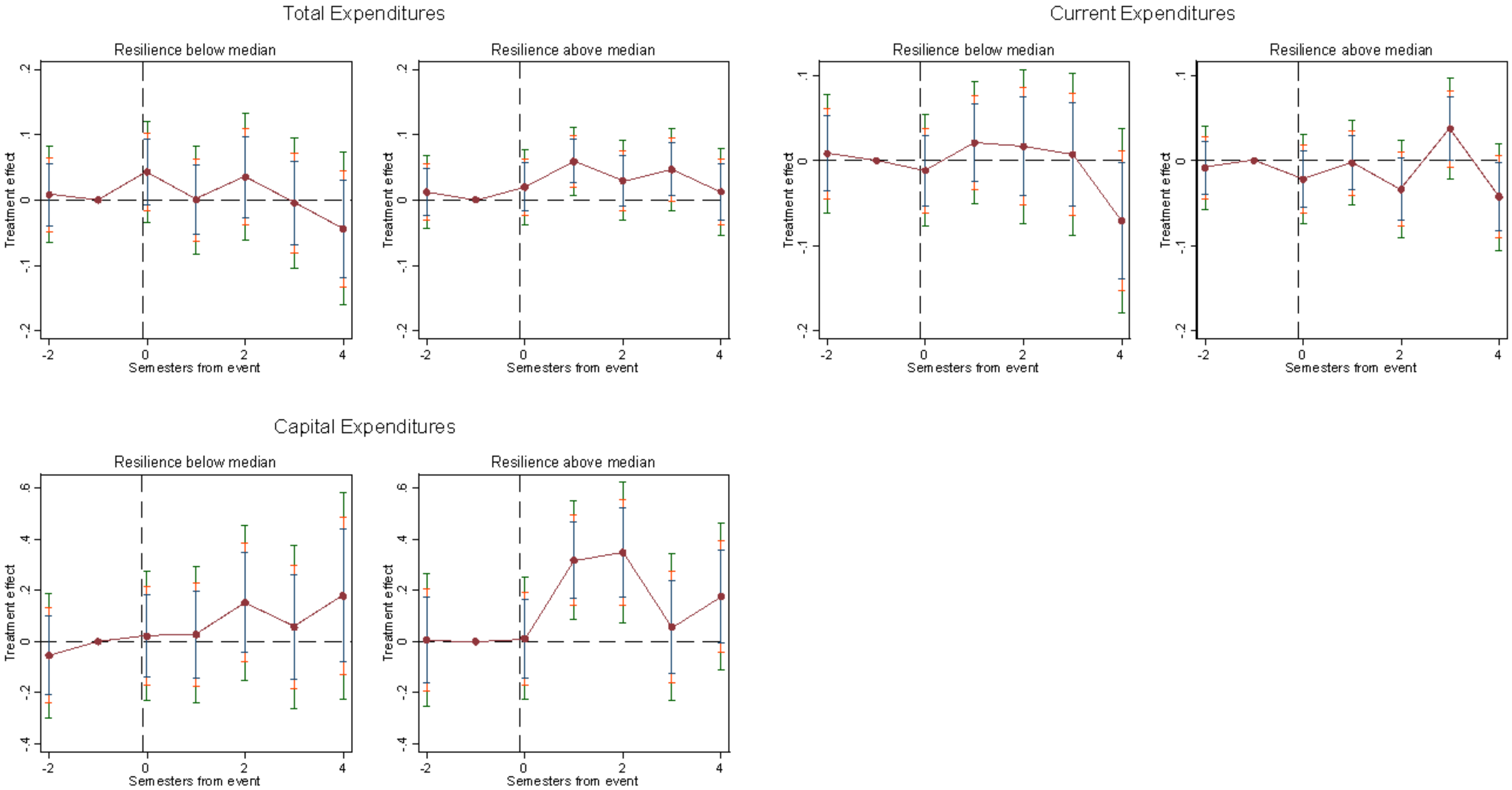
Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.

Figure C.2. Difference-in-differences baseline estimations - Revenues



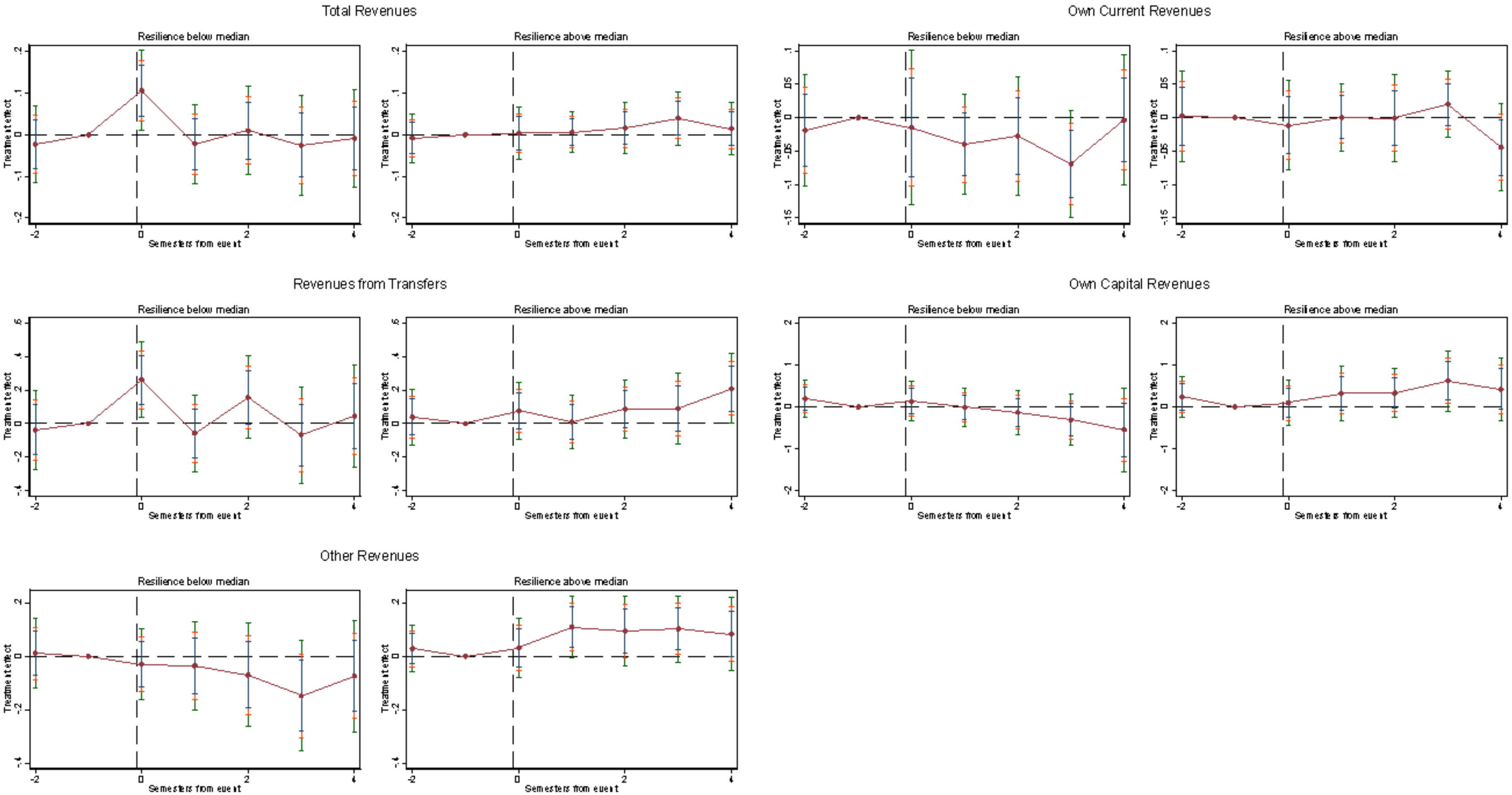
Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.

Figure C.3. Difference-in-Difference estimations by resilience level - Expenditures



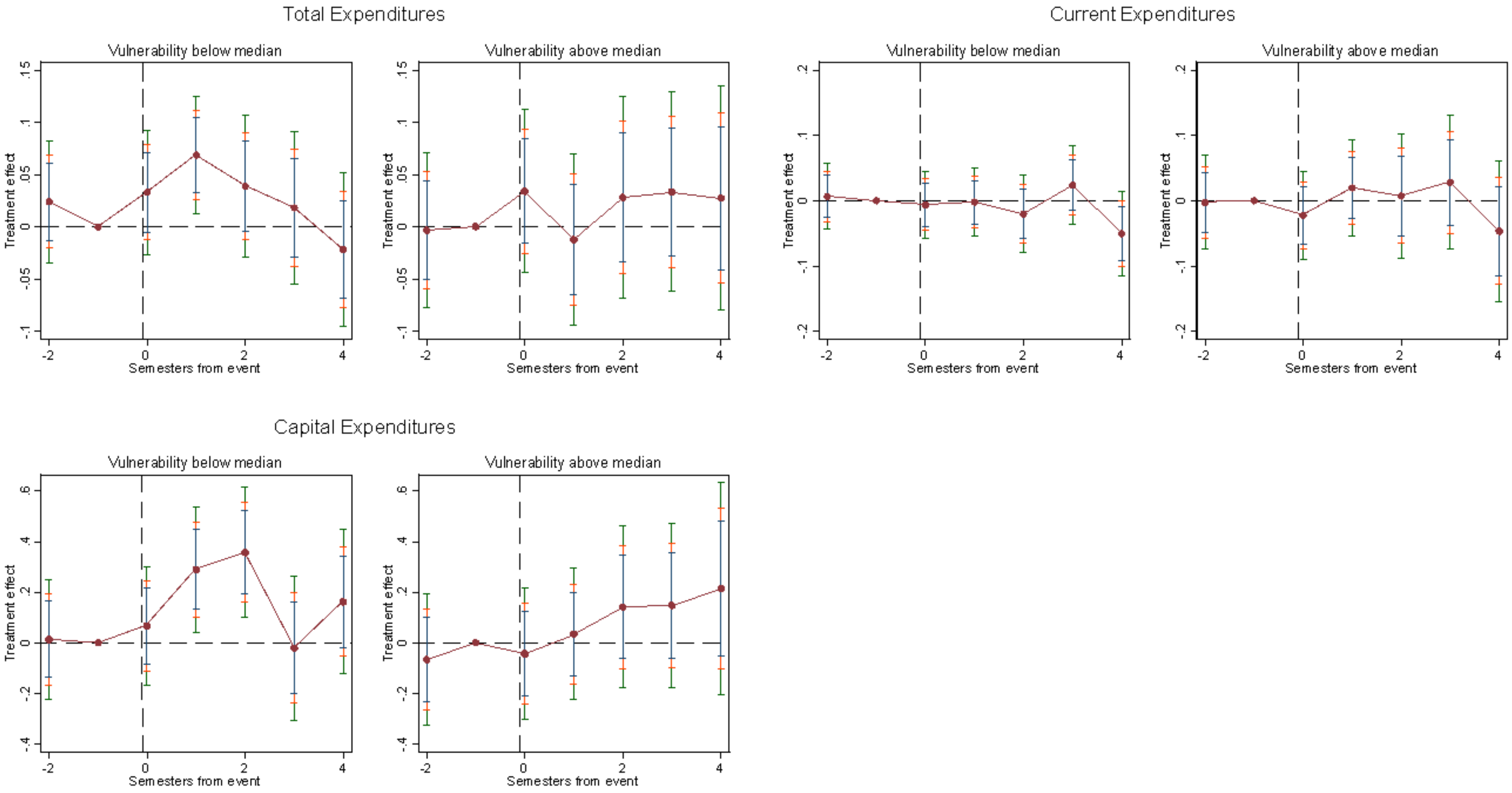
Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.

Figure C.4. Difference-in-Difference estimations by resilience level - Revenues



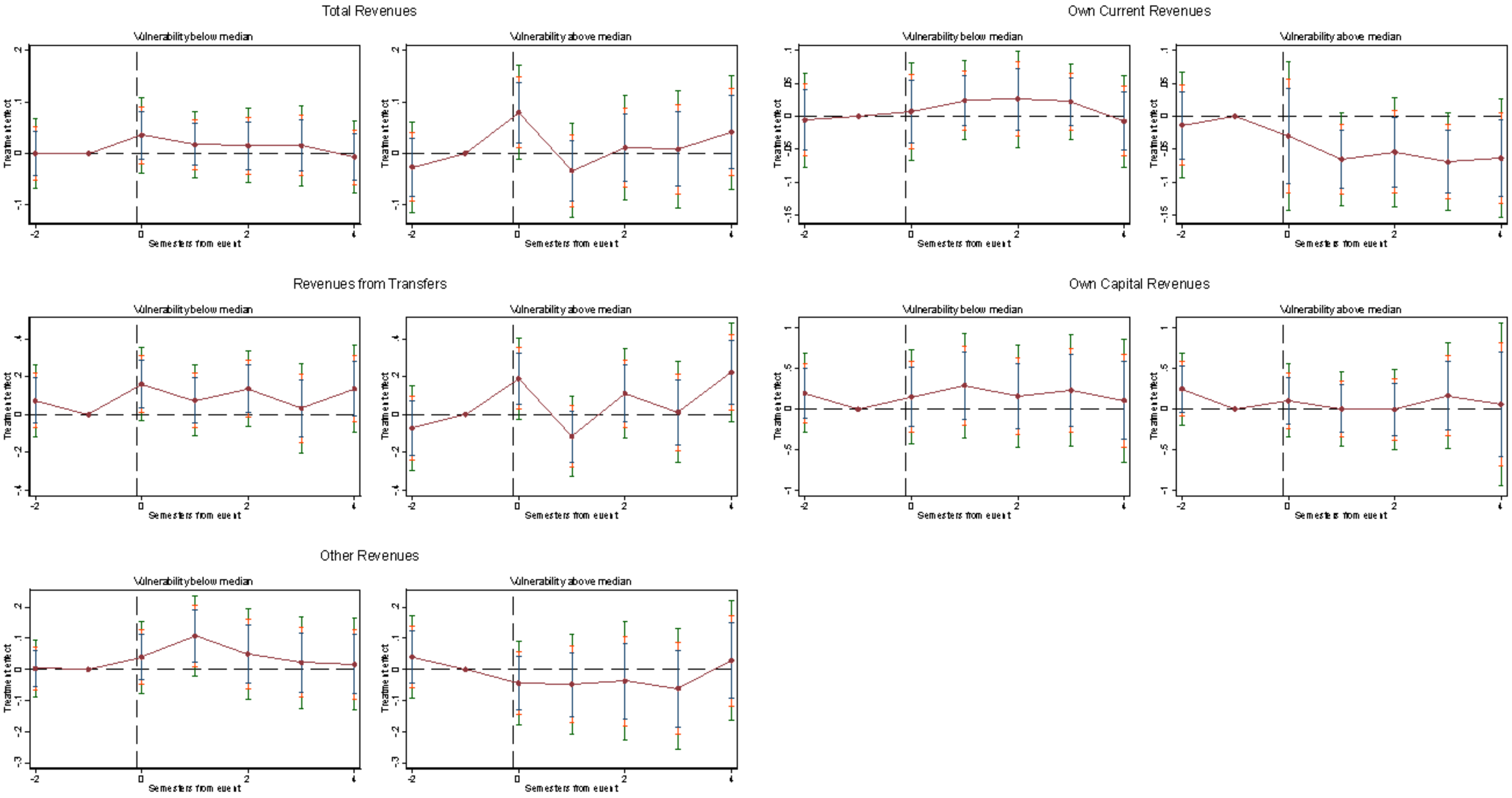
Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.

Figure C.5. Difference-in-Difference estimations by vulnerability level - Expenditures



Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.

Figure C.6. Difference-in-Difference estimations by vulnerability level - Revenues



Notes: three levels of statistical significance are reported. Blue p-value<0.1; Orange p-value<0.05; Green p-value<0.01.

Chiara Lodi: Conceptualization, Methodology, Data curation; Investigation; Formal Analysis; Validation; Writing - Original Draft Preparation; Writing - Review & Editing

Giovanni Marin: Conceptualization, Methodology; Formal Analysis; Validation; Supervision; Resources; Writing - Original Draft Preparation

Marco Modica: Conceptualization, Methodology; Formal Analysis; Supervision; Writing - Original Draft Preparation

Declaration of interests

☐The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Giovanni Marin reports financial support was provided by Italian Ministry of University and Research under the PRIN 2017 project 2017 7J2LS9004. Chiara Lodi reports financial support was provided by Italian Ministry of University and Research under the PRIN 2017 project 2017 7J2LS9004.