Municipalities' budgetary responses to natural disasters *

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Abstract

The aim of this paper is to examine the causal impact of natural disasters on municipalities' budgetary choices. I utilize an original database that enables the study of a sample comprising all French municipalities, of which 22,972 were affected by a natural disaster between 2000 and 2019. This exploratory analysis employs two distinct dynamic methodologies: Panel Vector Autoregression model and Difference in Difference, to estimate municipal responses to natural disasters. I show that a shock leads to an increase in spending and revenues in the aftermath of the disaster, followed by a decrease from 7 to 10 years later. Furthermore, I observe that municipalities with varying financial health appear to react differently.

Keywords : Local public finance, Local expenditure, Natural disasters

JEL Codes : H72, Q54, R50

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1 Introduction

Natural disasters are phenomena that affect all territories and that in a context of climate change may increase. Climate hazards potentially affect six out of ten French people (Antoni et al. 2020). Local governments are in the front line to manage these major climatic events and the damages associated with them. Municipalities are the first level of government and therefore the closest to the citizens in case of crisis. Moreover, such a disaster generates important costs for the municipalities, the example of the Roya valley in the south of France is relevant. Indeed, the reconstruction works of the infrastructures were estimated at 1 billion euro, for the destroyed roads, bridges, water and electricity networks... (Lenormand 2020). Nevertheless, few studies have looked at the impact of a shock on local public finances. The purpose of this study is to understand the impact of natural disasters on municipalities' budgets. I aim to understand how municipalities adjust their expenditures and revenues during post-shock management. I investigate whether municipalities are able to recover from natural disasters and to what extent they are resilient to shocks.

Shocks, and in particular natural disasters, have been studied in economics for their impact on GDP, growth and inflation, but also for their effects on poverty, household living conditions and firms (see the literature review by Kousky 2014). In contrast, the fiscal and budgetary consequences of natural disasters on governments have been less studied.

At the national level, several studies have examined the impact of disasters on central government finances. Noy and Nualsri (2011) conduct a comparative study of 42 developed and developing countries to understand the budgetary behavior of states after natural disasters. They show that developing countries have a pro-cyclical behavior, while developed countries have a counter-cyclical behavior, i.e. states increase their expenditures and decrease their taxes after a shock. Melecky and Raddatz (2011) show that developed countries are less impacted by natural disasters although they have an increase in their deficits. The authors also find that the higher the insurance protection, the lower the consequences of the disaster in terms of deficit.

However, the case of local public finance is different, local governments are responsible for public goods and infrastructure, for their population and for the return to normal life after the disaster (Fujiki 2017). Moreover, local governments are dependent on central government decisions, especially in terms of grants. For this reason, a part of the literature on natural disasters has focused on the effectiveness of central government grants on post-disaster economic and societal recovery. Valle et al. (2020), study the impact of grants on post-disaster recovery in Mexico. They show that grant funds can accelerate economic recovery from climate-related events. Masiero and Santarossa (2020) highlight a post-earthquake flypaper effect. They show that shock-specific grants boost government spending more than tax revenues and more than traditional grants.

On the other hand, some studies examine the reaction of local governments in the contexte of positive or negative shocks. Berset and Schelker (2020) focus on the impact of positive fiscal windfall. They show that municipalities increase premanently their expenditures which could leads to a fiscal windfall curse. Masiero and Santarossa (2020) look at the impact of natural disasters on municipal spending in Italy. They find an increase in total expenditures of earthquake-affected municipalities up to 12 years after the disaster. In contrast, Jerch et al. (2020), show that the expenditures and revenues of municipalities in the Southeastern United States decline in the 10 years following a hurricane. Moreover, they find a decrease in the allocation of local public goods in the impacted municipalities and even more if the municipal population is poor and low educated. These results seem consistent with empirical studies of local government responses to budgetary shocks which show that in the case of an expenditure shock, central government grants play a strong rebalancing role in European countries. While in the United States, expenditure shocks are mainly compensated by the municipality's own revenues (Buettner and Wildasin 2006 ; Buettner 2009 ; Solé-Ollé and Sorribas-Navarro 2012).

This study takes part of this literature and focuses on the impact of natural disasters on the budgetary behavior of French municipalities. Using the original database created from the accounts of French municipalities since 2000 as well as the compilation of all natural disasters that have occurred on the French territory, I analyze the causal link of natural shocks on different local accounts. This research provides new evidence of the increase in total expenditures of municipalities due to the occurrence of a natural disaster. I also observe a decrease from 7 to 10 years later The novelty of this study is that it focuses on several types of accounts. I analyze the effect on the main accounts, but also on sub-accounts in order to better understand how resources are used in post-disaster management. I show that following a climatic shock, municipalities increase their current expenditures, particularly current purchases and personnel expenditures. I also show that capital expenditures increase following a shock to finance new investments. The central government provides substantial support to municipalities through various types of grants. However, there has been an increase in tax revenues.

The remainder of this article is structured as follows. The second section describes the French institutional context.Section 3 presents the data. Section 4 presents the econometric approaches. Section 5 is devoted to the results, first for the main budgetary accounts, then for the sub-accounts. Before turning to the role of financial health. The final section concludes.

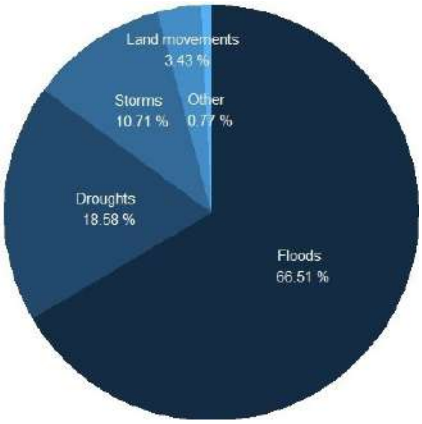
2 Institutional context

2.1 The particular features of natural disasters

Natural disasters are not any type of climatic event, indeed, a major meteorological event can be designated as a "natural disaster" in some particular cases. The status of natural disaster considers exceptional and non-standard meteorological events having an abnormal intensity, it concerns floods, mudflows, droughts, land movement, earthquake, storm, etc.

Natural hazards are of various natures, 53 types of risks are listed in the GASPAR (Gestion ASsistée des Procédures Administratives relatives aux Risques) database from the french ministry of environement. Figure 1 shows the distribution of natural disasters since 1982, the most common events are floods which represent more than half of the shocks, then droughts, storms

Figure 1: Share of Natural Disaster by type since 1982



Share of Natural Disaster by type since 1982. This figure shows the share of natural disasters that occurred between 1982 and 2020 at the municipal level by type of shock. The four main categories are floods, droughts, storms and land movements, from the darkest to the lightest color. *Source* : Data on natural disasters were provided by the Ministry of Ecology.

and land movements. On average, more than 3000 natural disasters are recorded per year, i.e. 64,930 shocks since 2000. Figure 2 shows that natural disasters are present throughout the territory. Since 1982, almost all French municipalities have faced at least one natural disaster, some of them being affected in a more recurrent way. Focusing on the occurrences of shock by type of natural disaster in the following figures 2a, 2b, 2c, 2d. I can notice that droughts affect mainly the center and the south west of France, while land movements are in the south east quarter of France. In addition, I can note that the floods although distributed on the whole territory, are more present along the rivers as well as on the coastal zones. As for the storms, I can notice that they affect more the coastal regions.

The status of "natural disaster" is important in the French case since it offers different insurance compensation compared to classic climatic shocks. The designation "natural disaster" is decided by ministerial decree after a request from the mayor of the municipality concerned. The case of France is atypical since private insurance and public reinsurance mechanisms are subordinated to the prior recognition of the status of natural disaster, which is not the case in many neighboring countries (Nachbar 2017).

Municipalities have an important role to play during a natural disaster, since the mayor is responsible for safety and crisis management, and must organize the protection and support of the population. The management of the natural disaster can generate additional costs supported by the municipalities. Indeed, the implementation of emergency services is the responsibility of the municipality such as transportation, emergency accommodation, communications... (De Choudens 2015). The costs are initially current expenses, then can be capital expenditures in a second time. The issue of natural disasters is also current in France since a new law on compensation for natural disasters has been enacted in December 2021, to make the procedures more transparent and more efficient. The main changes are: the inclusion in the law of the

Figure 2: Natural disasters in France since 1982

(a) Floods (b) Storms (c) Land mvmt (d) Droughts

Share of Natural Disaster by type since 1982. This figure shows the share of natural disasters that occurred between 1982 and 2020 at the municipal level by type of shock. A very weak exposure means that no more than two shocks have affected this municipality, a weak exposure corresponds to a municipality that has suffered a maximum of 5 disasters, a moderate exposure includes 5 to 10 shocks, a strong exposure means an exposure of less than 20 shocks, while a very strong exposure shows a municipality that has experienced more than 20 climatic events. *Source* :Data on natural disasters were provided by the Ministry of Ecology. The cartographic data comes from the OpenStreetMap cartographic database made available by the DGFiP.

role of the interministerial commission that makes annual assessments and statements on the reference systems used to assess the abnormal intensity of natural phenomena. In addition, a national consultative commission on natural disasters is created and whose objective will be to re-evaluate the criteria of natural disasters, as well as a group of referent to help municipalities in the administrative steps. Finally, the time limit for declaring a damage is extended to 2 years and the time limit for reimbursing the victims is shortened[1].

2.2 Administrative organization: governments' roles and grants

This study on the impact of natural disasters on local government budgetary decisions uses French data that allow us to analyze this issue, but this requires attention to the specific institutional context. A particularity of France is that it has about 35,000 municipalities, more than half of them have less than 500 inhabitants and more than 80% have less than 2000 inhabitants. These tiny jurisdictions create a particular institutional context, especially with regard to politics. On the other hand, it is important to note that France is a decentralized country with several levels of government: the central government, regions, counties (departments), inter-municipal cooperation (EPCI) and municipalities. Each level of government has specific competencies. The municipalities are responsible for local roads, schools, sports and cultural facilities, parks and gardens, maintenance of sewage systems, and waste treatment. The counties are responsible for rural roads, ports, colleges, museums, and are also involved in other areas such as childhood, disability, the elderly, and social assistance. The regions are responsible for national parks, river ports, airfields, high schools, they also finance infrastructure, railroads. The distinction between the roles of each level of government is important because during natural disasters, the management of the infrastructure is the responsibility of the one on which it depends, i.e. the renovation of a museum will be the responsibility of the county, while that of a school will be the responsibility of the municipality. The mayors are also responsible at the time of the crisis for the safety of the population, the preparation and the organization of the rescue. In the event of a crisis, the roles of each local authority are sometimes intertwined, which can cause certain difficulties. However, the mayors of the municipalities concerned remain responsible for the safety of the population.

The costs related to natural disasters can be of several types, on the one hand the current costs related to the care and safety of the population. Secondly, there are costs related to the deterioration of the municipality's assets and thirdly, costs related to the prevention of future disasters. Municipalities have two ways of financing their current expenditures: taxes and government grants. On average, since 2000, grants have accounted for a quarter of current revenues, while tax revenues have accounted for 40%. On the other hand, investments are financed by grants (36% on average), loans (20% on average) or by their own cash flow. However, it is not easy to determine which type of expenditure (security, repair or prevention) is linked to which type of account (current or investment account).

For costs related to the damage caused by the disaster, municipalities may be assisted in

[1] Law n° 2021-1837 of December 28, 2021 relating to the compensation of natural disasters

offsetting these costs in various ways. Part of the municipality's assets are insured, such as buildings for example, these assets then benefit from the natural disaster clause according to the insurance code[2], if a decree has been published. However, some of the municipality's assets are not insured, such as roads, engineering structures, parks and water distribution networks.

These assets are then eligible for compensation called "solidarity grant for the equipment of local authorities and their groups affected by climatic or geological events" and is a merger since 2016 of the two former devices: "the solidarity fund for local authorities affected by natural disasters" and "the equipment grant to local authorities for the repair of damage caused by public disasters". The rate and the amount of this grant are graduated according to the weight of the damage in the budget of the affected jurisdiction [3]. In addition, when a natural disaster decree is issued, local authorities that are beneficiaries of the Value Added Tax Compensation Fund (FCTVA)[4] can obtain a refund of the VAT for investment expenses (Requillart 2014). Finally, other grants can be requested to carry out investment work, such as the local investment support grant (DSIL) or the rural territory equipment grant (DETR), if the municipalities meet the criteria. (Maurey 2019).

3 Data

To create the database for this study, which includes 34,627 municipalities between 2000 and 2019, I use several sets from different institutions. The first set is the database of French municipal accounts between 2000 and 2019 available from the Ministry of Public Accounts. This database offers us several variables about the budgetary behavior of municipalities, thanks to different indicators of the operating, investment, self-financing and debt accounts (see table 2 in the appendix for all indicators).

The second set comes from the GASPAR database (Gestion ASsistée des Procédures Administratives relatives aux Risques) i.e Assisted Management of Risk Administrative Procedures, available from the Ministry of Ecology and it is composed of the decrees of natural disasters since 1982. These data allow us to know exactly when a municipality was affected by a natural disaster and the type of disaster it is (flood, mudslide, land movement, drought, etc.). This database provides information on the dates and types of shocks, but a limitation is the lack of information on the intensity of natural disasters or on the damage caused.

Finally, the third part of the database corresponds to the control variables. Thus, data on the characteristics of municipalities are available on the one hand from INSEE (National Institute of Statistics and Economic Studies) for demographic and socio-economic information, and on the other hand from the General Directorate of Public Finance (taxation, type of municipal cooperation). In addition, electoral data are available from the Ministry of the Interior.

[2]article L.125-1 of the insurance code

[3]article R.1613-9 of the general code of local authorities (code général des collectivités territoriales)

[4]article L.1615-6 III of the general code of local authorities (code général des collectivités territoriales)

4 Methodology

4.1 Difference in Difference approaches

4.1.1 Two-ways Fixed Effect model

In order to analyse the effect of natural disasters on municipal budget outcomes, I use an econometric model inspired by Gallagher (2014), Berset and Schelker (2020) and Masiero and Santarossa (2020). Our panel of municipal budget data (2000 - 2019) along with natural disaster information allows us to build the following model:

$$Y_{i,t} = \sum_{\tau=0}^{12} \beta_\tau Shock_{i,\tau} + X_{i,t}\gamma + \mu_i + \theta_t + \varepsilon_{i,t} \tag{1}$$

The dependent variable $Y_{i,t}$ is the logarithm[5] of one municipality's account, which can be current expenditures, capital expenditures, total expenditures or other subaccounts. Our main variable of interest is the variable $Shock_{i,\tau}$ which represents the natural disaster, it is a dummy variable equal to 1 when the disaster occurs, i.e. $Shock_{i,0} = 1$ the year that municipality i is affected by a natural disaster and $Shock_{i,1} = 1$ if municipality i has been affected by a natural disaster last year. I also consider a vector of municipal characteristics $X_{i,t}$, which includes several time-varying financial, socio-demographic, socio-economic and institutional covariates as well as time-invariant variables about their environmental situation. Specifically, these are the logarithms of operating grants and subsidies received by the central government, tax revenues and loans of municipalities. The political and institutional variables are the number of years before the next election, the type of inter-municipal cooperation and the region to which the municipality belongs. The socio-economic and socio-demographic variables are the size of the population, the logarithm of the median income per capita, the share of unemployed in the municipality's population, the share of people under 20 years old and the share of people over 65 years old. Finally, the environmental variables concern the geographical location, i.e. whether the municipality is in a mountainous or coastal area, as well as whether it is in an urban or rural area and its county.

To estimate the proposed model for this analysis, various estimators can be employed. Firstly, a pooled OLS model could yield a consistent estimate. Its advantage lies in its ability to control for time-invariant environmental situations, such as the geographical position of the municipality, whether it is located in the mountains or on the coast. However, this estimator does not consider the temporal dependence between observations and does not control for unobserved time-invariant heterogeneity, as a fixed effect model would.

A random effects model has the advantage of providing a consistent and efficient estimate when the model assumptions are satisfied. It also controls for time-invariant observed factors.

[5] The use of the logarithm was chosen according to the literature on econometric models of natural disasters. However, this use led us to perform a transformation on the variables by adding a constant equal to 0.001, in order to lose a minimum of data during the logarithm transformation.

Nevertheless, the assumptions of this model are demanding, and the estimate becomes spurious if the assumption of independence of time-invariant errors is violated.

The chosen model is, therefore, a fixed effect regression. I decided to exclude pooled OLS and random effect regressions, as they do not address unobserved time-invariant heterogeneity. This choice is supported by both pooling and Hausman tests.

The selected fixed effect estimator is the within estimator, allowing us to retain more information compared to a first difference or between estimator. Additionally, White's robust covariance matrix enables us to control for heteroscedasticity and serial correlation.

However, this methodology raises endogeneity issues. The first problem highlighted by Masiero and Santarossa (2020) documents that certain explanatory variables, such as grants received from the central government, could be influenced by municipal expenditures. In this case, I face a problem of reverse causality, which would bias an OLS estimator. However, a Within estimator with fixed effects controls for these time-invariant factors that could lead to endogeneity.

The second problem could result from the fact that the shock may also impact certain regressors. For example, a natural disaster may be assumed to have an effect on residents' income. In this case, the shock coefficient could be biased. To test this endogeneity issue, I estimate the model with and without control variables. I do not observe a significant difference between the two estimations; they both align in the same direction.

Thirdly, various types of inter-municipal links may play a role in municipal budgetary responses. For instance, the role played by an inter-municipality may differ depending on the type of integration requested by the constituent municipalities. In an EPCI where municipal integration is strong, territorial solidarity in the event of a natural disaster may be more significant than in cases where integration is weaker. To control for these differences, a variable considering the types of EPCI is added. This is a categorical variable considering communities of communes, urban communities, metropolitan communities, and those that do not belong to an EPCI or lack independent taxation (as the reference category). It is observed that this variable, along with the electoral variable, appears to capture effects related to institutional contexts. The inclusion of these control variables is, therefore, crucial.

Another point concerns a confounding factor that could bias the estimation. An unobserved factor may have an effect on both the occurrence of a natural disaster and municipal expenditures. For example, if a municipality chooses to build infrastructure along a river in a potentially dangerous area, this could increase the risk of flooding and still constitute a municipal expense. Conversely, a municipality wishing to limit its expenses may choose to maintain its river facilities less regularly, affecting the risk of a disaster. To mitigate this endogeneity problem, I could check for the existence of a risk prevention plan in the municipality. The objective of such a plan is largely to raise awareness of disaster risks in a municipality and to delineate potentially risky areas to limit constructions, among other measures. These decisions could introduce a bias into the observation of the disaster[6]. We, therefore, add prevention plans as control variables. This is a dichotomous variable equal to 0 if there is no prevention plan and equal to 1 when a prevention plan is created and active in the respective years. The addition of this control variable does not change the results presented in the following section. However, a second issue arises since natural risk prevention plans (PPRN) also pose an endogeneity question. Indeed, a PPRN is endogenous to both past shocks or a municipality's exposure to risk and probably to the intensity or cost of future shocks suffered, as the purpose of a prevention plan is to limit the impact of a shock. This reverse causality problem is a real limitation of this analysis and would require an ad hoc identification method to overcome it.

Furthermore, to ensure the robustness of the results, different estimations are carried out based on the duration or type of disaster experienced by the municipality. Additionally, I also test sensitivities by considering only a subset of municipalities based on the timing and number of shocks they have experienced (see Section .3).

However, the Two Ways Fixed Effect (TWFE) model is questioned in recent literature (Sun and Abraham 2020, Callaway and Sant'Anna 2021, Chaisemartin and D'Haultfoeuille 2022). It is demonstrated that the estimated coefficients could be contaminated by the effects of other periods. Therefore, in addition to the TWFE model, I use a Staggered Difference in Difference approach and I rely on another part of the literature concerning the impact of natural disasters on public expenditures using a dynamic panel model (PVAR).

4.1.2 Staggered Difference in Difference

The objective is to observe the causal link of the occurrence of a natural disaster on municipal budgets. Our panel of municipal budget data (2000 - 2019) along with natural disaster information allows to conduct an event study employing a difference-in-differences (DiD) and multiple time periods methodology *à la* Callaway and Sant'Anna (2021).

The first methodology enables estimation of the effect of a natural disaster shock, while taking account of the unpredictable nature of the shock. A natural disaster can occur at any moment so the treatment includes multiple time periods. A municipality is considered treated from the year when it suffered a natural disaster, and remains in the control group for as long as it remains untreated ("Not yet treated" group). Once a municipality has experienced a natural disaster, it remains in the treatment group, in line with the staggered treatment adoption assumption.

$$Y = \alpha_1^{s,t} + \alpha_2^{s,t} Shock_s + \alpha_3^{s,t} \mathbf{1}\{T = t\} + \beta^{s,t}(Shock_s \times \mathbf{1}\{T = t\}) + \gamma \mathbf{X} + \varepsilon^{s,t} \tag{2}$$

The outcome variable Y is one municipality's account per capita which can be total expenditures, revenues, grants or other subaccounts (current expenditures, investment expenditures, tax revenues etc...)[7]. The variable *Shock* represent the natural disaster, which is equal to 1

[6]The bias direction can be positive or negative, and it is challenging to determine if this bias is the same for all estimated coefficients. Since these coefficients are correlated, the bias direction will depend on the correlation with the unobserved effect and with the set of correlations between variables correlated with the effect

[7]I use the inverse hyperbolic sine transformation, in order to lose a minimum of data during the transformation.

if the municipality i is first treated in period s, i.e $Shock_{i,s} = \mathbf{1}\{Shock_i = s\}$. I also consider a vector for municipal characteristics $\mathbf{X}$, which includes several time-varying financial, socio-demographic and socio-economic covariates. Specifically, these are the logarithms of the municipality's debts and tax revenues. The socio-economic and socio-demographic variables are population size, share of people aged under 20 years, and the share of people aged over 65 years.

To analyze the effects of a natural disaster on the municipal budget, I use a special aggregation scheme which provides an understanding of how the average treatment effect evolves with the length of time of exposure to the treatment, i.e. event-study-type estimates.

Nevertheless, while attempting to control for many variables, I overlook the fact that all municipal budget accounts are interdependent and endogenous. Therefore, in addition to the DiD model, I draw on another part of the literature on the impact of natural disasters on public expenditures using a dynamic panel model (PVAR).

4.2 Panel Vector Autoregression Model

Panel Vector Autoregression Models (PVAR) are mainly used in the macroeconomic literature on natural disasters (Noy and Nualsri (2011), Melecky and Raddatz (2011)) and more recently this type of model has been applied at the local level (Miao, Hou, et al. (2018), Miao, Chen, et al. (2020), Panwar and Sen (2020)). The interest of this model is that it allows to estimate the dynamic effects of natural disasters on the budgetary behaviors of municipalities including expenditures, revenues debt and government grants. Moreover, this model allows for the integration of endogenous interactions between the dependent variables. Each dependent variable is determined by its own previous values as well as those of the other endogenous variables. I estimate the following empirical specification :

$$Y_{i,t} = \alpha_0 + \alpha Y_{i,t-1} + \sum_{j=0}^{5} \beta_{\tau-j} Shock_{i,\tau-j} + \mu_i + \theta_t + \varepsilon_{i,t} \tag{3}$$

Where $Y_{i,t}$ is the vector of log dependent variables i.e. $Y_{i,t} = (Expenditures_{i,t}$, $Revenues_{i,t}$, $Grants_{i,t}$, $Debt_{i,t})$. The variable $Shock_{i,\tau-j}$ as above is a dummy variable equal to 1 when the shock occurs, i.e. $Shock_{i,\tau-j} = 1$ if the natural disaster occurred in municipality i, j years ago $(j = 0, 1, 2, 3, 4, 5)$. I also find the municipal fixed effect μ_i and the time fixed effect θ_t.

The inclusion of fixed effects in a dynamic model can induce biases in the estimation, so I follow Holtz-Eakin and al (1988) and use the generalized method of moments (GMM) for estimation, using as instruments the lags of Y from $t-2$ to $t-3$. I remove the fixed effect using the Helmert transformation, i.e. forwards orthogonal deviation procedure. The choice of the number of lag and instrument is based on the BIC and AIC selection criteria. I first test the stationarity conditions according to the Im, Pesaran and Shin (2003) test, which allows us to reject the null hypothesis of the presense of unit root. I then construct the dynamic multiplicative functions (DMFs) by running a monte-carlo estimation of 500 iterations to compute the confidence intervals. This allows us to observe the dynamic impact of a natural disaster on the budgetary outcomes.

5 Results

5.1 Impact of natural disasters on the main municipal budget accounts

5.1.1 Fixed Effect Model

Table 1 reports the results of regressions based on the model of Equation (1). The objective here is to understand the disaster effect on the main accounts of municipalities. The dependent variables are total expenditures, total revenues, total subsidies, and debt in columns 1, 2, 3, and 4, respectively.

Additionally, as the dependent variable is transformed into logarithm, I can interpret the coefficients as percentages such that $(\exp^{\widehat{\beta}} - 1) \times 100$.

The first observation is a significant increase in total expenditures in the year of the natural disaster[8], as well as in the three years following the shock. The impact of the natural disaster is approximately 0.7% to 0.5% per year up to 3 years after it. The second column shows estimates based on the logarithm of total municipal revenues. I observe a significant increase in revenues after a natural disaster, with a rise of 0.7% in revenues in the year of the shock and up to 2 years after the disaster. These results indicate that the shock has a direct effect on revenues, which does not seem very persistent over time. The third column presents estimates of the effects on total subsidies, i.e., the sum of operating (DGF) and investment subsidies. These results show a significant increase in subsidies between the second year and the fourth year after the shock. This indicates that the increase in total revenues during the disaster is not due to a significant increase in subsidies from higher-level governments. Furthermore, the increase in subsidies between $t-2$ and $t-4$ does not cause a significant increase in total revenues. Finally, the fourth column shows estimates of the impact on debt. This column shows a 3.3% increase in debt at the time of the natural disaster. This is a strong impact that persists up to 4 years after the shock.

These results are consistent with the literature, which shows an increase in expenditure, revenue and debt. However, as this method only allows us to photograph the impacts at different points in time, the following analysis provides a better understanding of the dynamics of the shock.

5.1.2 Staggered Difference in Difference

The figure 3 reports the results of the regressions based on the model of the equation (2). The objective here is to understand the causal relationship of the occurrence of a shock to the main accounts of municipalities. The dependent variables are total expenditures, total revenues, total grants and debt, figure 3a, 3b, 3c and 3d respectively. The control group is composed of 12,184 municipalities that did not experience any natural shocks. The treatment group includes the 21,898 municipalities that had at least one shock between 2000 and 2019. However, until

[8] The year t represents the year when the shock occurred, the year $t-1$ is the following year, and so on up to $t-10$, which represents the 10th year after the occurrence of the disaster. If a municipality experiences multiple natural disasters, the count restarts with each new shock.

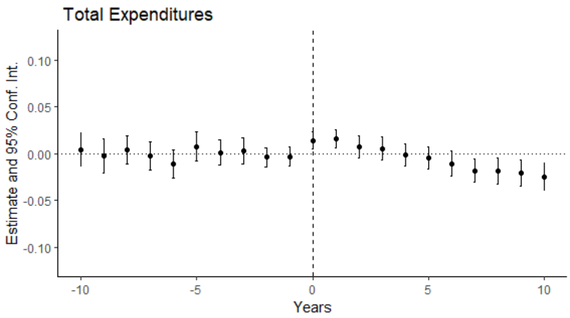
Table 1: Impact of Natural Disasters on Main Municipal Accounts

	Fixed Effects Model - Within Estimator			
	Total Expenditures	Total Revenues	Subsidies	Debts
Shock_t	0.007***	0.007***	−0.004	0.033**
	(0.002)	(0.002)	(0.006)	(0.014)
Shock_{t-1}	0.007***	0.004**	0.005	0.039***
	(0.002)	(0.002)	(0.006)	(0.015)
Shock_{t-2}	0.006***	0.004*	0.018**	0.041**
	(0.002)	(0.002)	(0.007)	(0.016)
Shock_{t-3}	0.005**	0.003	0.017***	0.038**
	(0.002)	(0.002)	(0.006)	(0.017)
Shock_{t-4}	0.004	0.001	0.015***	0.033*
	(0.002)	(0.002)	(0.005)	(0.018)
Shock_{t-5}	0.003	0.001	0.009	0.024
	(0.002)	(0.002)	(0.006)	(0.018)
Shock_{t-6}	0.002	−0.002	0.004	0.001
	(0.003)	(0.002)	(0.007)	(0.020)
Shock_{t-7}	0.002	0.003	0.006	0.001
	(0.003)	(0.003)	(0.008)	(0.020)
Shock_{t-8}	−0.003	0.001	0.005	−0.021
	(0.003)	(0.003)	(0.008)	(0.021)
Shock_{t-9}	0.001	−0.001	0.008	−0.028
	(0.003)	(0.003)	(0.009)	(0.021)
Shock_{t-10}	0.003	0.001	0.002	0.003
	(0.003)	(0.003)	(0.012)	(0.021)
Observations	629,244	629,244	629,244	629,244
Municipalities	34,393	34,393	34,393	34,393
R^2	0.183	0.233	0.207	0.010
Temporal Fixed Effect	Yes	Yes	Yes	Yes
Municipal Fixed Effect	Yes	Yes	Yes	Yes
Financial Control	Yes	Yes	Yes	Yes
Socio-economic Control	Yes	Yes	Yes	Yes
Sociodemographic Control	Yes	Yes	Yes	Yes
Institutional Control	Yes	Yes	Yes	Yes

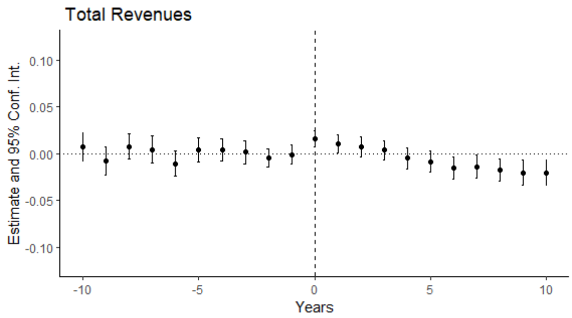
Note: *p<0.1; **p<0.05; ***p<0.01 ; All models control for financial (local tax and subsidy revenues), political (years before elections), institutional (type of inter-municipal cooperation), socio-economic (median income and percentage of unemployed), and sociodemographic (population size, percentage of young and elderly people) characteristics, as well as temporal and municipal fixed effects. Standard errors of estimated coefficients (in parentheses) are clustered for heteroskedasticity at the municipal level.

Figure 3: Effect of a natural disaster on the main budget accounts

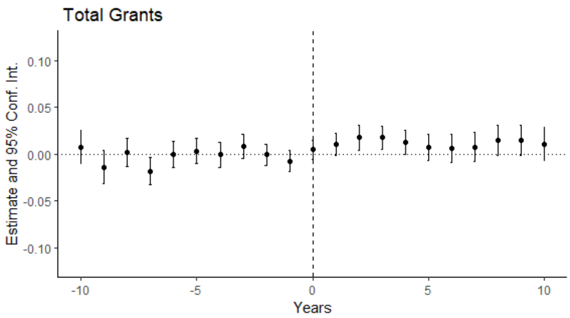
(a) Expenditures



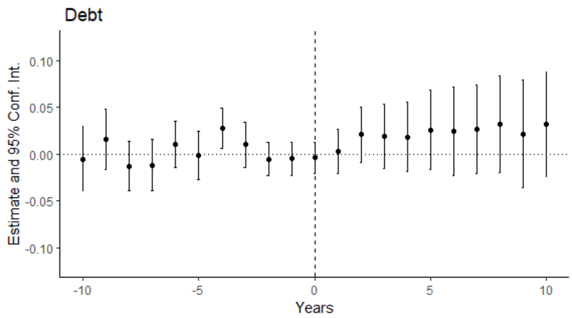
(b) Revenues



(c) Grants



(d) Debt



Note: Estimation of the effect of a major natural disaster on the budgetary accounts of French municipalities with with robust standard errors, using a staggered difference in difference event study methodology. The control variables consist of municipal budget elements, and municipal characteristics controls.

the first shock occurred, the municipality belongs to the control group.

Figure 3a shows a significant increase in total expenditures at the event of the natural disaster and the year after. The increase in total expenditure at the time of the shock seems to indicate the need for emergency spending. On the other hand, I have observed a reduction in this spending 7 years after the disaster. This indicates that municipalities are not maintaining their pre-disaster public spending levels.

Indeed, I can see from the figure 3b that the revenues react in the same way. Municipalities saw their revenues rise at the time of the shock, then decline 7 years afterwards.

This represents the key distinction observed in comparison to the earlier estimation. By considering the timing variability of natural disasters, this methodology has enabled the identification of a long-term negative impact on expenditures.

This is consistent with the results of Jerch et al. (2020), who found a significant decrease in local expenditures and revenues in the 10 years after a hurricane strike in USA.

Figure 3c shows the effects of natural disasters on total grants. I find that municipalities experience a significant increase in the amount of state grants during three years after the shock, likely due to the compensation to fund expenditure on recovery.

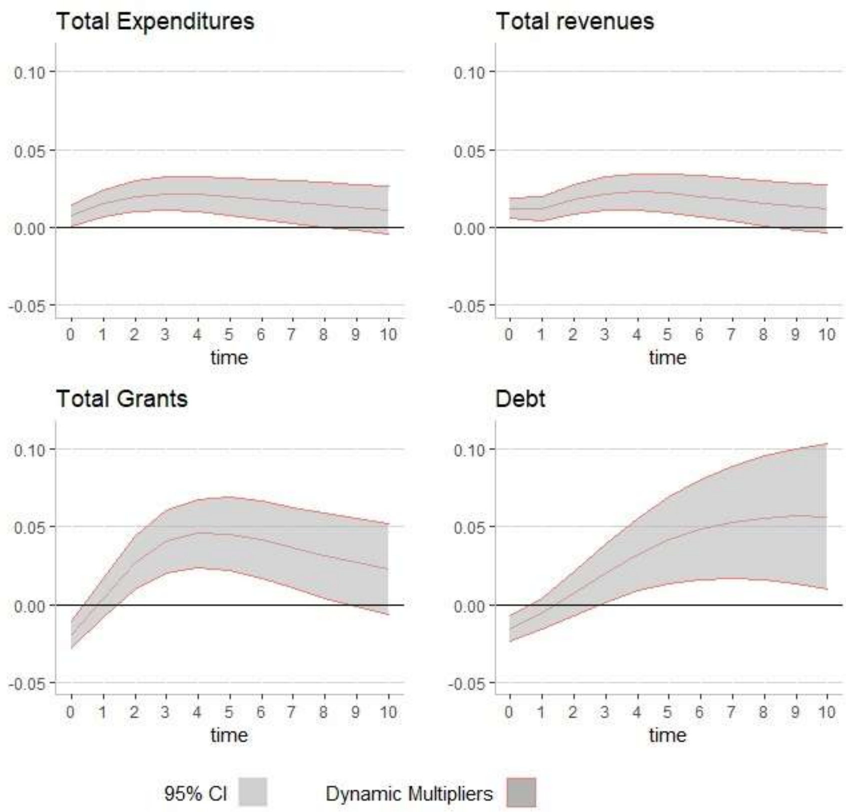
Finally, the figure 3d shows the effect on the municipal debt. Despite the positive coefficients, I find no significant effect of natural disasters on debt.

The results align with the previous estimation; however, this method does not allow to integrate the interaction between the municipal budget accounts. The following analysis provides a better understanding of the dynamics of the shock.

5.1.3 Panel Vector Autoregression Model

The figure 4 shows the dynamic responses of the PVAR model estimate of equation (3) (Table 3 in appendix presents the point estimates of the DMFs).

Figure 4: Dynamic Response of main accounts



Notes: These figures show the DMFs of debt, total revenues, total grants and total expenditure. Values on the x-axis indicate years after the shock, The y-axis represent the change in the account of the local gouvernment. Shaded area indicates the 95 percent confidence interval for the relevant dynamic multiplier function. *Source* : The database is constructed from natural disaster data available from the Ministry of Ecology and municipal accounts data from the Ministry of Public Accounts.

The estimated points represent the variation of the different variables following the occurrence of a natural disaster. As expected, the figure 4 shows a significant increase in total expenditures (top left) at the time of the shock. Expenditures increase up to 4 years after the disaster, and then growth declines in the longer-term post-shock period, which is consistent with the results of the previous estimate. This increase is significant in the 7 years after the shock, i.e. the effect is more persistent than in the previous estimate.

Subsequently, I can similarly see a significant increase in total revenue at the time of the shock, growing until the 4th year and then decreasing over time (top right).

Considering the grants (bottom left), I observe a significant decrease at the time of the shock. In the previous estimate, the effect was not significant. This is followed by a significant rise up to 4 years after the shock, before declining. This shows us that upper governments provide significant funding to municipalities following a disaster and maintain this support up to 8 years after the shock.

Finally, looking at the response of municipal debt (bottom right) reveals a decrease at the time of the shock. Thereafter, I notice a significant increase in debt up to 10 years after the shock. It is not surprising to observe that local governments take on debt following a natural disaster in order to finance the excess spending that can be observed. The results on debt represent the major difference with those of the previous estimate. Taking into account the endogeneity of the budget accounts, allows to observe a significant and presistent increase in municipal debt.

These results seem to be consistent in the majority with the DiD estimate, but show more precisely the dynamics of the responses and seem to indicate a persistence in the post-disaster reactions.

5.2 Impact of natural disasters on the sub-accounts

The results of the budget sub-accounts showed that expenditures increased after the occurrence of a shock. These results made wonder about the types of expenditure that are involved in this increase. Figure 5 shows the effect of natural disasters on salary expenditures, current purchases, capital expenditures and loan repayments, in order to understand more precisely the effects of a natural disaster on the budgetary choices of municipalities.

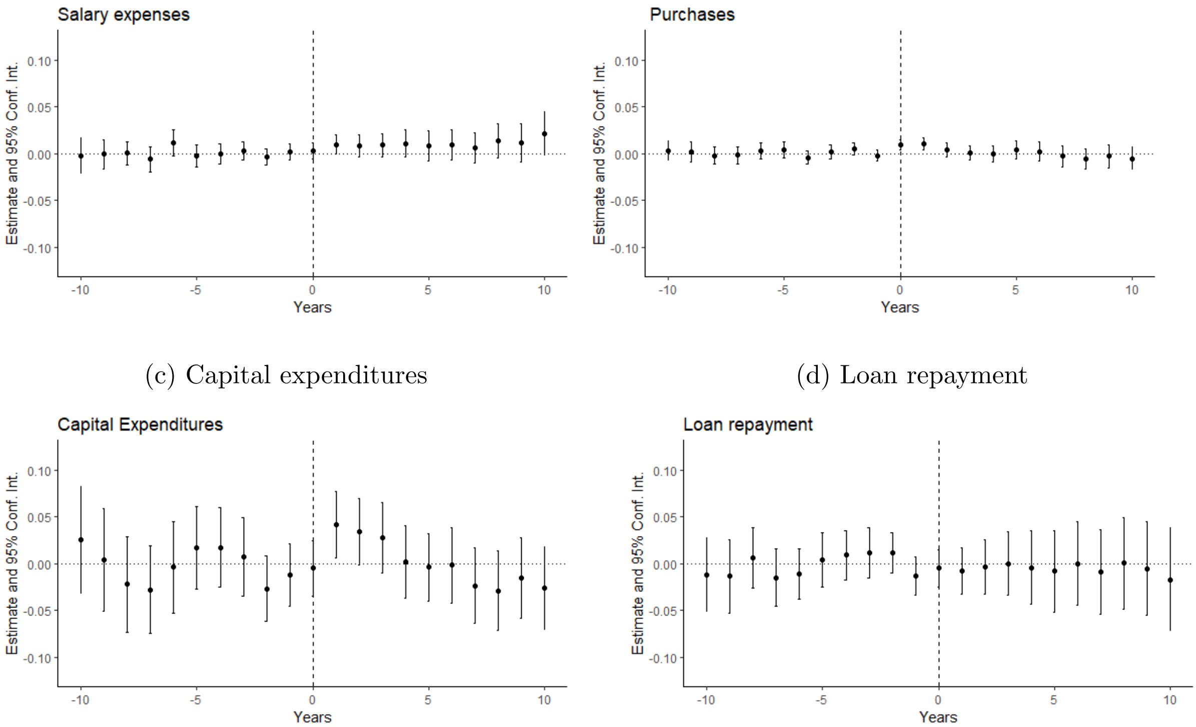
Figure 5a and 5b concern current expenditure. Thoses figures show that salary expenses increase significantly in year after the shock and purchases increase in the event of the disaser and the year after.

Figure 5c and 5d are part of investment expenditures. Capital expenditures considered here are only for the acquisition of new capital, not for repair costs. I observe here an increase 2 years following the disaster, which means that municipalities are able to finance new investments. Concerning loan repayments, I don't observe any significant effect.

This analysis of the sub-accounts allows us to better understand the choices made by municipalities following a natural disaster. However, I would need more detailed accounts to be able to push our analysis even further.

On the other hand, I examine the extent to which municipal revenue levers are affected by a shock. These levers are of different types, first operating grants (DGF i.e. Dotation Globale de Fonctionnement) allocated according to different criteria, in particular the wealth of the municipality. Then, investment grants determined according to the projects of the municipalities. Another type of revenue is tax revenue, as well as loans contracted by municipalities. In

Figure 5: Effect of a natural disaster on the expenditure sub-accounts



(a) Salary expenses (b) Purchases (c) Capital expenditures (d) Loan repayment

Note: Estimation of the effect of a major natural disaster on the budgetary accounts of French municipalities with with robust standard errors, using a staggered difference in difference event study methodology. The control variables consist of municipal budget elements, and municipal characteristics controls.

the accounts of the municipalities, operating grants and tax revenues are considered as current revenues (Figures 6a and 6b) and investment grants and loans are investment revenues (Figures 6c and 6d).

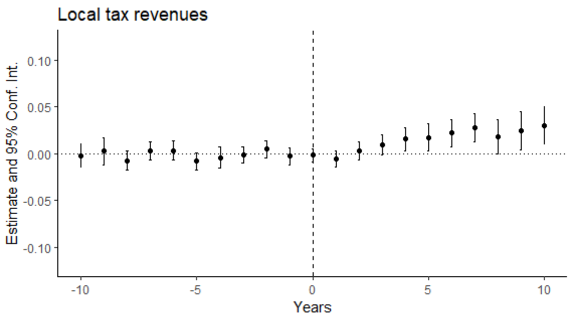
First, regarding tax revenues, there is a significant increase from the third year after the shock to the 10th year. Local taxes seem to be an important lever for municipalities to compensate for their increased expenses, but only in a second time after the occurrence of the shock.

Indeed considering grants, I see that operating and investment grants react differently to a shock. I observe that investment grants are impacted the second year and the third year after the shock. Operating grants increase the 7th year to the 10th year. It is assumed that this type of grants does not increase at the time of the shock, as municipalities receive other types of subsidies to help them compensate for the damage of the disaster (such as the solidarity grant for climate events, which is not included in these data). At the time of the shock, municipalities would receive specific grants for natural disasters, then apply for investment grants and lastly see their operating grants increase over the longer term.

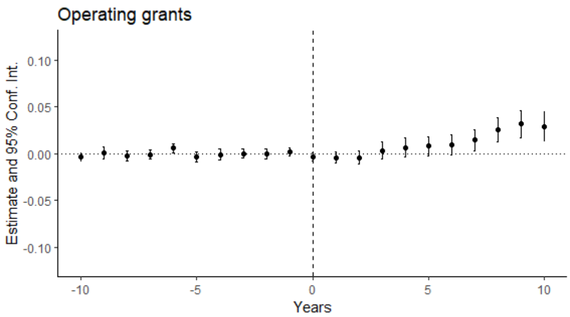
Finally, the figure 6d shows the effect of natural disaster on contracted loans. I observe a significant decrease the 9th year after a disaster. This means that the municipalities reduce their loans after the 9th year.

Figure 6: Effect of a natural disaster on the revenue sub-accounts

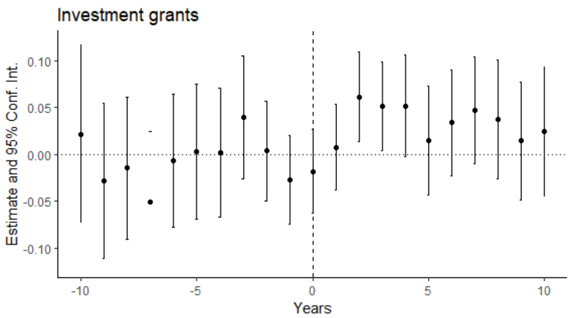
(a) Local tax revenues



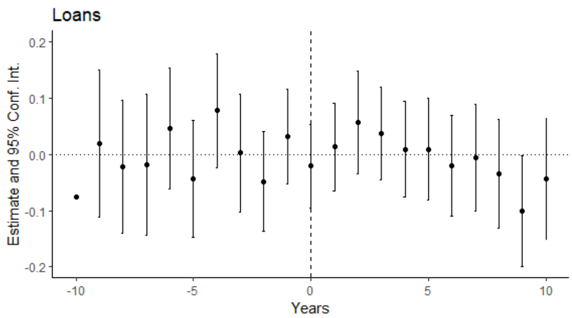
(b) Operating grants



(c) Investment grants



(d) Loans



Note: Estimation of the effect of a natural disaster on the budgetary accounts of French municipalities with with robust standard errors, using a staggered difference in difference event study methodology. The control variables consist of municipal budget elements, and municipal characteristics controls.

I have also estimated these effects with a fixed-effects panel model; the short-term results are very similar. However, the results at the end of the period are more divergent. This discrepancy can be explained by the bias in this type of model when the treatment occurs at multiple timings.

These results show that natural disasters have a significant effect on local authority budget accounts and sub-accounts. Municipalities use various levers to offset natural disasters, and in particular different types of grants.

5.3 Financial health: a key factor in recovery

Natural disasters have significant effects on the finances of municipalities. However, the impact of these disasters can vary depending on the financial capabilities of the municipalities. Financial health can be defined as the financial state of a municipality, especially in terms of its borrowing and savings capacity. Thus, I aim to highlight the impact of natural disasters on municipalities with different financial health statuses.

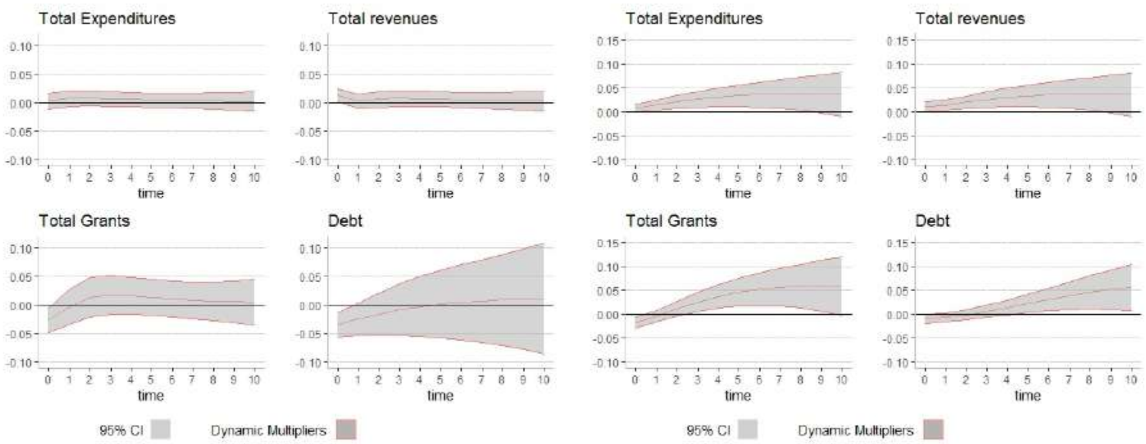
To achieve this, I use a financial health rating established by the Agence France Locale (AFL). This AFL rating serves as an indicator of the sound budgetary functioning of local authorities. It is calculated based on various indicators such as debt, self-financing capacity, and savings. This rating provides us with a variable signaling the average financial health level of each municipality, ranging from 1 to 7, where 1 indicates municipalities in very good financial health and 7 those in a precarious situation.

To analyze the role of financial health in the impact of natural disasters on municipal budgets, I create several samples of municipalities. The first sample is the ”very good” group, including municipalities with an average rating between 1 and 2.5 from 2000 to 2019. The second group, the ”good” group, contains municipalities with a rating higher than 2.5 and lower than 4.5, while the third group considers municipalities with a rating higher than 4.5.

I then apply the dynamic PVAR model described in Section 4.2 to compare the reactions of the different groups.

Figure 7: Dynamic response of main accounts

(a) Group 1: ”Very good” (b) Group 3: ”Average or poor”



Notes: These figures show the DMFs of debt, total revenues, total grants and total expenditure. Values on the x-axis indicate years after the shock, The y-axis represent the change in the account of the local gouvernment. Shaded area indicates the 95 percent confidence interval for the relevant dynamic multiplier function. *Source* : The database is constructed from natural disaster data available from the Ministry of Ecology and municipal accounts data from the Ministry of Public Accounts.

The figures 7a and 7b present the results of the analyses on the different rating groups. I focus our analysis on groups 1 and 3; other results are available in the appendix. The results first show significant differences between group 1 and group 3. In the first group, i.e., municipalities with a very good average financial health, the impact of natural disasters is low. The effect of the shock on the main accounts of the municipalities, although significant at the time of the shock, is not persistent. I observe no long-term effect for these municipalities, as well as no impact on debt. This suggests that financially healthy municipalities can easily recover from a natural disaster, possibly by utilizing their own resources.

Conversely, municipalities in the third group, those with average to poor financial health on average, see their budgets strongly affected by the shock. I observe a significant and positive impact of the shock on expenses, revenues, and received subsidies. Thus, considering the cumulative effect over 10 years, I observe an increase in expenses of about €845 per inhabitant and an increase in revenues of €950 per inhabitant, including €360 in subsidies. Furthermore, I observe an increase in municipal debt with a delay of several years. This may indicate that financially unhealthy municipalities cannot incur new debts at the beginning of the period. However, the cumulative effect over 10 years corresponds to a 27% increase in debt, or €270 per inhabitant on average.

On the other hand, estimates for the second group, municipalities with average financial health, show an increase in budgets following a shock. These effects, however, are less persistent than those of the third group. In contrast, the increase in the debt of these municipalities occurs more rapidly after the disaster.

Therefore, I notice that municipalities with different financial health statuses also have different reactions to shocks. The more degraded the financial health, the more persistent the impact of natural disasters will be on the budgets of local authorities. The next section presents robustness tests conducted to support the validity of the main results.

5.4 Robustness Checks

The robustness of the main results is ensured by several tests that allow us to certify the impact of natural disasters on the budgetary responses of municipalities.

I conducted several tests to demonstrate the robustness of our results for the impact of natural disasters on municipalities' budgetary responses. First, I conducted a falsification test to check for the presence of a placebo effect. To detect any possible effect, I performed the same regressions as conducted for the baseline results observing the year prior to the shock.

Clearly, there is no significant effect in the pre-shock periods on the graphs 3a, 3b, 3c and 3d. I also perform the TWFE regressions as for the baseline results by observing the year prior to the shock, to detect a possible effect (appendix table 6) The results of this test show that there is no significant effect on municipal accounts in the year before the shock. Moreover, the common trend hypothesis is verified from Figure 8 in Appendix. For this purpose, I observe the pre-shock trends for the control and treatment groups.

One of the limitations of our research is that I do not control for the intensity of the natural disaster events. To analyse the intensity I use the EM-DAT database (International Disaster Database, CRED). This international database selects catastrophic events of extreme intensity. EM-DAT records human and economic losses with at least one of the following criteria: 10 fatalities, 100 affected people, a declaration of state of emergency and a call for international assistance.

I then estimate the DiD model by considering only these extreme events, and observe results of a similar magnitude to the baseline (see figure 11 in Appendix).

I create a sample with municipalities that have only experienced one shock over the period 2000-2019, a second sample with those that have not experienced a shock before 2000, i.e., that have no shock history, and finally a third sample where I exclude municipalities that have experienced a shock after 2015, in order to understand whether there is an habituation to shocks. The results seem to be in line with the baseline results. However, I note that municipalities that have only experienced one shock seem to react with slightly more intensity than the baseline sample. This could be explained by the habituation of municipalities that have already experienced shocks. However, if I look at the sample of municipalities that had never experienced a shock before 2000, I notice that the impacts are very weak. So on the contrary, the municipalities that have no experience of shocks seem to resist better. However, this result should be treated with caution, since the sample is very small compared to the others (n = 652) and may be composed of municipalities with very specific characteristics.

I also try to measure the treatment based on the duration of the disaster, as I assume that the duration of the shock can be an indicator of its intensity. I then assign treatment in three different ways. First, the treatment group concerns municipalities that experienced shocks that lasted less than one month, the second treatment concerns shocks of less than one week, and then shocks of one day or less. The results are consistent with the baseline results for high intensity shocks (more than one week and more than one month). But I observe that when the disaster lasts one day or less, municipal expenditures are much less affected, except for debt, which increases significantly.

Finally, the last test is based on the type of disaster. I choose to observe floods on the one hand, and droughts on the other, these events being both the most frequent and the most opposite. The results concerning floods are in line with the basic results, with a slightly more intense effect than when considering all types of disaster. However, when considering only droughts, the impact of droughts on spending is not significant in the event of the shock. However, it appears that municipalities spend less following 5 years after a shock. This may be because drought does not have the same impact on municipalities as floods. Indeed, a flood may require an evacuation of the population and cause material damage, while a drought will mainly affect agriculture and health, which does not cause the same costs for the municipalities.

I also perform the baseline regressions using municipal expenditures and revenues with raw data (not per capita), the results are broadly similar to those in euros per capita. All the test results tables are available in the appendix in section .3.

6 Discussion and conclusion

The aim is to investigate how municipalities faced with a natural disaster modify their budgetary behavior in terms of expenditures and revenues. Natural disasters are major exogenous climatic events whose probability of occurrence is likely to increase in the coming years. The exogenous nature of these shocks allows us to conduct an event study to identify the causal effect of a shock on local government budgets. To carry out this study I use data from the accounts of French municipalities since 2000 as well as all natural disasters since 1982. I analyze the causal effect of a natural disaster on several budget accounts and sub-accounts.

Municipalities are the local governments closest to the people and thus first in line in case of a natural disaster. Moreover, municipalities have a duty to their residents to maintain public services in all circumstances. Natural disasters have adverse effects on municipalities. Indeed, additional costs arise when a shock occurs. The municipality must first rescue and protect the population, then is in charge of the return to normal life while maintaining the local public assets. Secondly, the local government has to implement the reconstruction and repair of the damage and finally the prevention of future risks.

I observe a significant increase in total expenditure from the time of the shock and for a few years thereafter. The sub-accounts show us that there is a significant increase in spending on new investments in the year following the shock. Then I note a decrease in the growth of expenditures and even a drop in total expenditure after 7 years, which is consistent with the findings of Jerch et al. (2020) for U.S. hurricanes.

In response, I observe symetrical effect on total revenues. I observe an increase in grants, first of all investment grants that start 2 years after the shock, and then operating grants that are provided afterwards. This increase in grants shows that the central government is supporting the municipalities. I thus see that central government assistance through grants is necessary as suggested by Masiero and Santarossa (2020) and Miao, Hou, et al. (2018), but is not the only lever used by municipalities to offset for the increase in expenditures.

At the time of a natural disaster, tax revenues may be impacted. It is expected that tax revenues will decrease due to a fall in tourism in the municipality and the potential damage to local businesses. Then during the aftermath, several effects can be assumed to compete with each other. As before, some businesses have been damaged or wish to leave, and a decrease in tourism is expected, which would lower tax revenues. However, our results show an increase in tax revenues for 10 years with a three-year delay after the disaster. This can be explained by the new post-shock investments that have boosted the municipality. On the other hand, I can suppose that the municipalities use the shock to increase their tax revenues on the long term, the citizens being more likely to accept a tax increase.

The third lever that can be used by municipalities is borrowing, although no significant effect has been seen.

However, these effects on all French municipalities can mask certain situations. When I group municipalities by financial health indicator, I notice that reactions differ. Indeed, municipalities in better financial health seem less affected financially by the disaster, unlike those in poorer financial health.

The absence of a theoretical model on this issue hinders a deeper understanding of municipalities' budgetary responses to natural disasters. The goal of this event study is to initiate an initial analysis of these behaviors; however, it does not allow for a detailed identification of effects and mechanisms.

To delve further into this issue, a theoretical model guiding us on post-catastrophe spending mechanisms would provide a better understanding of these exploratory results and also facilitate the precise modeling of the effects of a shock on local government accounts.

A second limitation is the availability of data and information on natural disasters. Here, a natural disaster is represented by an indicator variable, which provides no information on the extent, intensity, or damages. By assuming that all natural disasters are similar, I overlook the great diversity of what they can entail. Reducing a natural disaster to an indicator leaves endogeneity problems unresolved. Omitting the magnitude of the disaster introduces a bias whose sign I cannot identify given the dynamic complexity of the model. Reducing a natural disaster to an indicator and thus omitting its magnitude results in a loss of information, increasing the estimator's variance.

Other identification challenges should be considered to move beyond the exploratory approach. On one hand, although the type of inter-municipal cooperation is controlled, the geographic interdependence of municipalities needs to be addressed. Municipalities are part of EPCI (public inter-municipal cooperation establishments), which can also be affected by a disaster when one or more municipalities are impacted by a shock. Given territorial solidarity, it can be assumed that inter-municipal cooperation may provide assistance in the event of a disaster, affecting the expenditures of a municipality that has not experienced a natural disaster directly. To disentangle these effects, i.e., a municipality affected but not directly hit by a shock, a model with multiple decision-making levels, including a level of government higher than the municipality in addition to the central government and banks, would be necessary. This would help understand the interconnections between the different actors affected by climatic events.

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.1 Descriptive statistics

Table 2: Descriptive statistics of municipal accounts

	minimum	median	mean	maximum
Current Account				
Current Revenues	-848.7	739.2	856.8	31,664.4
Local taxes	-11,317.9	241.0	282.9	9,227.0
Other taxes	-4,882.37	37.20	60.27	3,672.41
Operating Grant	-97.78	184.04	207.85	3,421.14
Current Expenditures	52.33	579.97	674.84	26,652
Salary expenses	-540.3	200.0	236.3	2,804.0
Purchases	4.529	175.198	203.366	9,302.440
Accounting result	-20,144	135.04	177.1	28,427
Investment Account				
Investment Revenues	-125.2	330.8	496.8	38,232
Loans	-841.52	0.00	82.02	12,634
Investment grants	-269.20	49.26	115.12	16,102.72
Investment Expenditures	-431.6	324.8	492.6	32,819
Capital expenditure	-1,648.2	235.6	375.3	25,783
Loan repayment	0.00	46.83	70.78	9,833
Self-financing				
Cash flow	-7,487.35	154.73	191.45	30,909
Debt				
Total debt	-153.8	418.6	575.7	16,094
Municipal Characteristics				
Population	2	430	1,714	870,018
Surface area (km^2)	0.04	10.84	15.42	758.93
median revenue (€)	75.97	18,248	18,347	233,109
Share of the population under 20 years old (%)	0.00	24.32	24.09	98.46
Share of the population over 65 years old (%)	0.00	18.32	19.57	100
unemployment rate (%)	0.00	7.61	8.69	100

Descriptive statistics of municipalities This table shows the descriptive statistics of the different municipal accounts and municipal characteristics. It is based on a sample of 34,627 French municipalities between 2000 and 2019. These statistics are expressed in euro per capita. *Source* : The database is constructed from natural disaster data available from the Ministry of Ecology, municipal accounts data provided by the Ministry of Public Accounts and the characteristics of the municipalities from INSEE (National Institute of Statistics and Economic Studies).

.2 Additionnal results

.2.1 PVAR

Table 3: Dynamic Impact of Natural disaster on local gouvernments main accounts

	year τ	τ-1	τ-2	τ-3	τ-4	τ-5
Expenditures	0.007 *	0.015 ***	0.020 ***	0.0217 ***	0.021 ***	0.020 ***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Revenues	0.012 ***	0.012 **	0.0179 ***	0.0216 ***	0.0226 ***	0.0218 ***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Grants	-0.019 ***	0.004	0.027 **	0.040 ***	0.0456 ***	0.045 ***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Debt	-0.015 ***	-0.0057	0.007	0.020 *	0.032 **	0.041 **
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
	τ-6	τ-7	τ-8	τ-9	τ-10	
Expenditures	0.018 **	0.016 *	0.014 *	0.0127 .	0.011	
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
Revenues	0.020 **	0.0177 *	0.015 *	0.013 .	0.0118	
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
Grants	0.0416 ***	0.03679 **	0.031 *	0.0267 .	0.0226	
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
Debt	0.048 **	0.053 **	0.0556 **	0.0567 *	0.056 *	
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	
Observations	420,744					
Municipalities	33,787					

Note : $^{\cdot}$p<0.1; *p<0.05; **p<0.01; ***p<0.01 ; For Monte Carlo simulations, 500 replications were used in the computation of standard errors as indicated in parentheses.

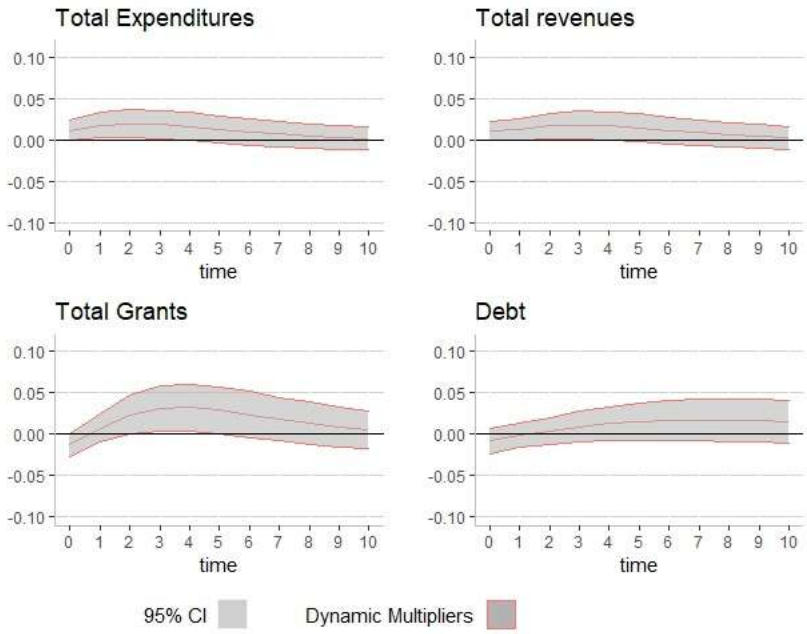
.2.2 Sub-accounts : Expenditures

Table 4: Impact of Natural disaster on local gouvernment expenditures - sub-accounts

	Fixed Effect model - Within Estimator			
	Current Expenditure		Investment Expenditure	
	Salary expenses	Purchases	Capital expenditure	Loan repayment
Shock_{τ}	0.002	−0.001	0.0005	0.057***
	(0.005)	(0.005)	(0.008)	(0.013)
$\text{Shock}_{\tau-1}$	0.008*	0.001	0.030***	0.072***
	(0.004)	(0.005)	(0.009)	(0.015)
$\text{Shock}_{\tau-2}$	0.004	−0.004	0.026*	0.090***
	(0.005)	(0.004)	(0.016)	(0.015)
$\text{Shock}_{\tau-3}$	0.007	−0.004	0.024**	0.111***
	(0.006)	(0.005)	(0.011)	(0.018)
$\text{Shock}_{\tau-4}$	0.007	−0.005	−0.002	0.106***
	(0.006)	(0.005)	(0.021)	(0.020)
$\text{Shock}_{\tau-5}$	0.004	−0.002	0.001	0.105***
	(0.006)	(0.005)	(0.016)	(0.023)
$\text{Shock}_{\tau-6}$	0.015**	0.0005	0.004	0.097***
	(0.006)	(0.005)	(0.008)	(0.023)
$\text{Shock}_{\tau-7}$	0.001	−0.002	−0.002	0.072***
	(0.006)	(0.003)	(0.023)	(0.021)
$\text{Shock}_{\tau-8}$	0.008	−0.009***	−0.023	0.049*
	(0.006)	(0.002)	(0.025)	(0.025)
$\text{Shock}_{\tau-9}$	0.007	−0.003	0.007	0.074***
	(0.006)	(0.003)	(0.026)	(0.022)
$\text{Shock}_{\tau-10}$	0.010	−0.004	0.013	0.050
	(0.008)	(0.004)	(0.024)	(0.037)
Observations	628,994	628,994	628,994	628,994
Municipalities	34,393	34,393	34,393	34,393
R^2	0.341	0.387	0.180	0.124
Year fixed effects	Yes	Yes	Yes	Yes
Municipalities fixed effects	Yes	Yes	Yes	Yes
Financial controls	Yes	Yes	Yes	Yes
Socio-economic controls	Yes	Yes	Yes	Yes
Socio-demographic controls	Yes	Yes	Yes	Yes
Institutional controls	Yes	Yes	Yes	Yes

Note : *p<0.1; **p<0.05; ***p<0.01 ; All models control for financial time-variant characteristics (revenues from local taxation, from grants and from loans), political (years before elections), institutional (type of inter-municipal cooperation, state fixed effect), socioeconomic (median income and percent of unemployement) and sociodemographic factors (population size, percent of young, and percent of old population), and year fixed effects. Heteroskedasticity-consistent Standard errors in parentheses, using White's covariance matrix.

.2.4 Financial health : Group 2



.2.3 Sub-accounts : Revenues

Table 5: Impact of Natural disaster on local gouvernment revenues - sub-accounts

	Fixed Effect model - Within Estimator			
	Current Revenue		Investment Revenue	
	Local taxes	Operating Grant	Investment grants	Loans
Shock_{τ}	0.003	-0.008^{**}	0.055^{***}	-0.003
	(0.003)	(0.004)	(0.016)	(0.029)
$\text{Shock}_{\tau-1}$	0.001	-0.013^{***}	0.066^{***}	0.025
	(0.003)	(0.005)	(0.018)	(0.032)
$\text{Shock}_{\tau-2}$	0.011^{***}	-0.001	0.067^{***}	0.063^{*}
	(0.003)	(0.004)	(0.019)	(0.035)
$\text{Shock}_{\tau-3}$	0.014^{***}	-0.001	0.078^{***}	-0.003
	(0.003)	(0.005)	(0.021)	(0.037)
$\text{Shock}_{\tau-4}$	0.014^{***}	0.002	0.032	-0.052
	(0.003)	(0.005)	(0.022)	(0.040)
$\text{Shock}_{\tau-5}$	0.015^{***}	0.012^{***}	-0.001	-0.072^{*}
	(0.004)	(0.005)	(0.024)	(0.042)
$\text{Shock}_{\tau-6}$	0.019^{***}	0.010^{*}	-0.002	-0.187^{***}
	(0.004)	(0.005)	(0.026)	(0.045)
$\text{Shock}_{\tau-7}$	0.019^{***}	0.013^{**}	0.016	-0.122^{**}
	(0.004)	(0.006)	(0.028)	(0.048)
$\text{Shock}_{\tau-8}$	0.020^{***}	0.024^{***}	-0.064^{**}	-0.182^{***}
	(0.004)	(0.006)	(0.030)	(0.050)
$\text{Shock}_{\tau-9}$	0.013^{***}	0.019^{***}	-0.013	-0.244^{***}
	(0.005)	(0.007)	(0.031)	(0.054)
$\text{Shock}_{\tau-10}$	0.018^{***}	0.015^{**}	-0.029	-0.055
	(0.004)	(0.007)	(0.034)	(0.058)
Observations	629,286	629,244	629,244	629,244
municipalities	34,627	34,627	34,627	34,627
R^2	0.057	0.145	0.257	0.034
Year fixed effects	Yes	Yes	Yes	Yes
Municipalities fixed effects	Yes	Yes	Yes	Yes
Financial controls	Yes	Yes	Yes	Yes
Socio-economic controls	Yes	Yes	Yes	Yes
Socio-demographic controls	Yes	Yes	Yes	Yes
Institutional controls	Yes	Yes	Yes	Yes

Note : *p<0.1; **p<0.05; ***p<0.01 ; All models control for financial time-variant characteristics (current and investment expenditures and revenues), political (years before elections), institutional (type of inter-municipal cooperation, state fixed effect), socioeconomic (median income and percent of unemployement) and sociodemographic factors (population size, percent of young, and percent of old population), and year fixed effects. Heteroskedasticity-consistent Standard errors in parentheses, using White's covariance matrix.

.3 Robustness Checks

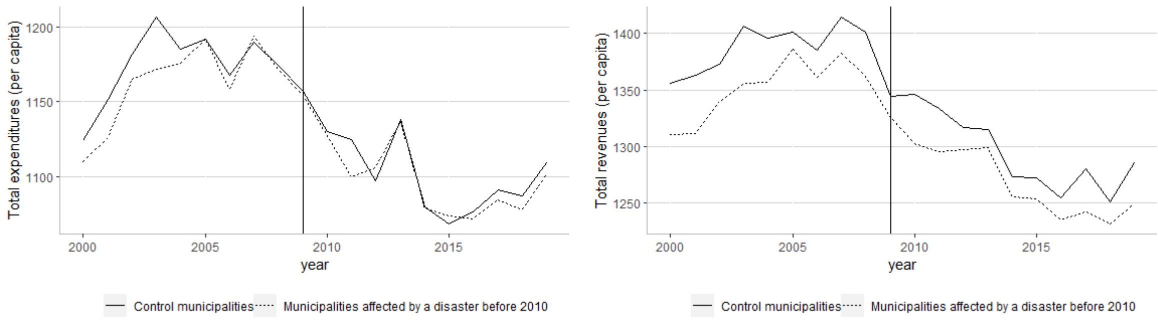
.3.1 Placebo test

Table 6: Placebo Test

	Fixed effect model - Within estimator			
	Expenditures	Revenues	Grants	Debt
Shock_{t+2}	−0.0001	0.002	−0.006	0.025
	(0.002)	(0.002)	(0.004)	(0.016)
Shock_{t+1}	0.001	0.004	−0.007	0.023
	(0.002)	(0.002)	(0.004)	(0.017)
Shock_{t}	0.003*	0.007***	−0.010*	0.039*
	(0.001)	(0.002)	(0.005)	(0.016)
Shock_{t-1}	0.004**	0.005**	−0.015**	0.045**
	(0.001)	(0.002)	(0.005)	(0.017)
Shock_{t-2}	0.003*	0.004*	−0.003	0.047**
	(0.002)	(0.002)	(0.005)	(0.018)
Shock_{t-3}	0.003*	0.004	−0.002	0.044*
	(0.002)	(0.002)	(0.005)	(0.019)
Shock_{t-4}	0.005**	0.002	0.001	0.040*
	(0.002)	(0.002)	(0.005)	(0.019)
Shock_{t-5}	0.005**	0.001	0.010*	0.030
	(0.002)	(0.002)	(0.005)	(0.020)
Shock_{t-6}	0.004*	−0.001	0.008	0.008
	(0.002)	(0.002)	(0.006)	(0.021)
Shock_{t-7}	0.004*	0.004	0.011	0.008
	(0.002)	(0.003)	(0.006)	(0.022)
Shock_{t-8}	0.004*	0.002	0.022**	−0.015
	(0.002)	(0.003)	(0.007)	(0.022)
Shock_{t-9}	0.004*	−0.0003	0.018*	−0.023
	(0.002)	(0.003)	(0.007)	(0.022)
Shock_{t-10}	0.006**	0.002	0.013	0.009
	(0.002)	(0.003)	(0.007)	(0.021)
Observations	629,244	629,244	629,244	629,244
R^2	0.097	0.233	0.145	0.010

Note : *p<0.05; **p<0.01; ***p<0.001 ; Tous les modèles contrôlent les caractéristiques financières (recettes de la fiscalité locale et des Grants), politiques (années avant les élections), institutionnelles (type de coopération intercommunale), socio-économiques (revenu médian et pourcentage de chômeurs) et sociodémographiques (taille de la population, pourcentage de jeunes et pourcentage de personnes âgées), ainsi que les effets fixes temporels et municipaux. Les écarts types des coefficients estimés (entre parenthèses) sont corrigés pour l'hétéroscédasticité groupée (clustering) au niveau municipal.

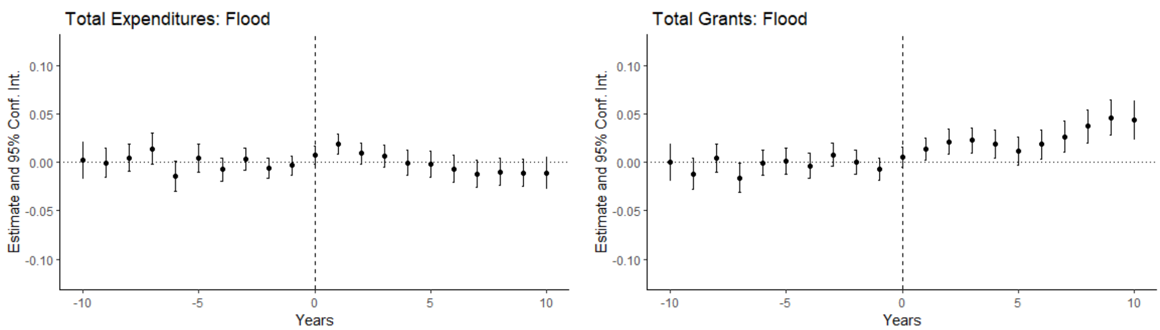
Figure 8: Common Trend



Source : The database is constructed from natural disaster data available from the Ministry of Ecology and municipal accounts data from the Ministry of Public Accounts.

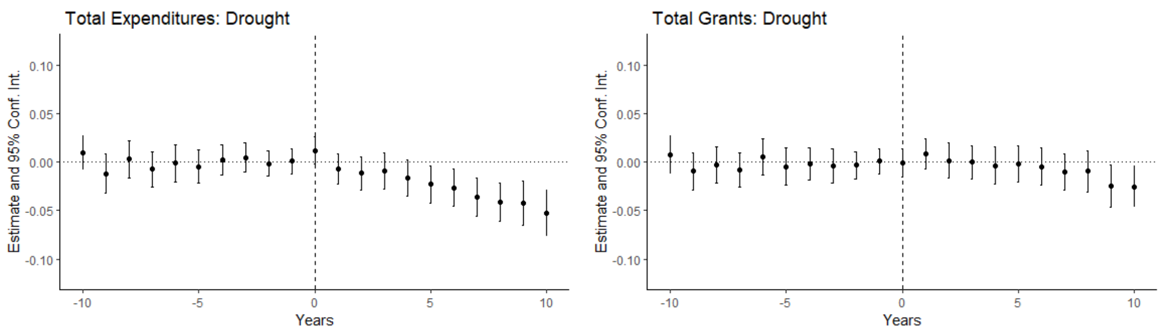
.3.2 Type of shocks

Figure 9: Flood



Source : The database is constructed from natural disaster data available from the Ministry of Ecology and municipal accounts data from the Ministry of Public Accounts.

Figure 10: Drought



Source : The database is constructed from natural disaster data available from the Ministry of Ecology and municipal accounts data from the Ministry of Public Accounts.

.3.3 Sensitivity and Intensity analysis

Table 7: Sensitivity Analysis of the Impact of Natural Disasters on Local Government Expenditures

	Fixed Effects Model - Within Estimator								
	Single Shock			No Previous Shock			No Shocks After 2015		
	Expenditures	Revenues	Debts	Expenditures	Revenues	Debts	Expenditures	Revenues	Debts
$Choc_t$	0.009**	0.007**	0.045*	0.031*	0.016	0.131	0.013***	0.011***	0.072***
	(0.004)	(0.003)	(0.025)	(0.016)	(0.015)	(0.119)	(0.003)	(0.003)	(0.021)
$Choc_{t-1}$	0.007*	0.007**	0.074***	−0.028	0.012	0.079	0.008***	0.006**	0.065***
	(0.004)	(0.003)	(0.026)	(0.019)	(0.017)	(0.134)	(0.003)	(0.003)	(0.023)
$Choc_{t-2}$	0.008*	0.005	0.071**	0.011	0.013	0.050	0.004	0.004	0.077***
	(0.004)	(0.004)	(0.029)	(0.019)	(0.019)	(0.168)	(0.003)	(0.003)	(0.024)
$Choc_{t-3}$	0.001	0.001	0.035	0.044*	0.035*	0.108	0.001	0.001	0.049**
	(0.004)	(0.004)	(0.030)	(0.024)	(0.021)	(0.156)	(0.003)	(0.003)	(0.025)
$Choc_{t-4}$	0.008*	0.005	0.007	0.011	0.018	0.199	0.002	0.001	0.044*
	(0.005)	(0.004)	(0.031)	(0.023)	(0.021)	(0.161)	(0.003)	(0.003)	(0.025)
$Choc_{t-5}$	0.012***	0.005	−0.0002	0.023	0.014	0.102	0.006*	0.003	0.029
	(0.004)	(0.004)	(0.032)	(0.025)	(0.022)	(0.209)	(0.003)	(0.003)	(0.025)
$Choc_{t-6}$	0.003	0.001	−0.040	0.002	0.001	0.100	0.004	0.001	−0.004
	(0.004)	(0.004)	(0.033)	(0.024)	(0.023)	(0.225)	(0.003)	(0.003)	(0.027)
$Choc_{t-7}$	0.003	0.004	−0.024	0.045*	0.026	0.175	−0.0003	0.002	−0.006
	(0.005)	(0.004)	(0.033)	(0.027)	(0.026)	(0.182)	(0.004)	(0.003)	(0.027)
$Choc_{t-8}$	−0.004	−0.005	−0.046	0.017	0.037	0.127	−0.007**	−0.002	−0.041
	(0.005)	(0.004)	(0.033)	(0.029)	(0.029)	(0.188)	(0.004)	(0.003)	(0.027)
$Choc_{t-9}$	−0.002	0.0001	−0.055*	0.025	0.023	−0.001	−0.003	−0.002	−0.046*
	(0.005)	(0.004)	(0.032)	(0.030)	(0.028)	(0.181)	(0.004)	(0.003)	(0.027)
$Choc_{t-10}$	0.002	0.0002	−0.019	0.072*	0.048	0.224	−0.001	−0.0005	−0.010
	(0.005)	(0.005)	(0.032)	(0.038)	(0.030)	(0.228)	(0.004)	(0.004)	(0.027)
Observations	364,344	364,344	364,344	10,068	10,068	10,068	390,786	390,786	390,786
Municipalités	20,591	20,591	20,591	652	652	652	21,906	21,906	21,906
R^2	0.183	0.234	0.010	0.261	0.343	0.017	0.184	0.234	0.010

Note: p<0.1; p<0.05; p<0.01; All models control for financial characteristics (local tax and grant revenues), political factors (years before elections), institutional features (type of intermunicipal cooperation), socio-economic factors (median income and percentage of unemployed), and sociodemographic aspects (population size, percentage of youth, and percentage of elderly), as well as time and municipal fixed effects. Standard errors of the estimated coefficients (in parentheses) are corrected for clustered heteroscedasticity at the municipal level.

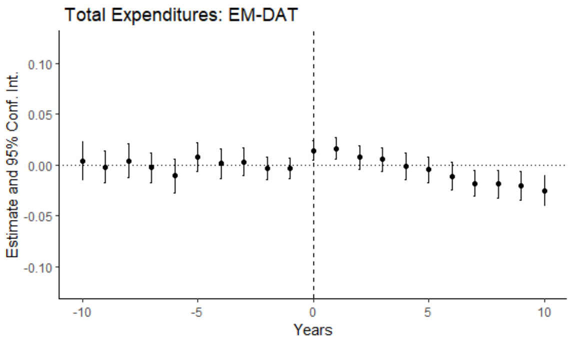
Table 8: Impact of Natural Disasters on Local Government Expenditures Using Different Disaster Frequency Measures

	Fixed Effects Model - Within Estimator								
-1.8ex]	Less than one month			Less than one week			Less than or equal to one day		
	Expenditures	Revenues	Debts	Expenditures	Revenues	Debts	Expenditures	Revenues	Debts
$Choc_t$	0.012***	0.012***	0.036*	0.011***	0.010***	0.026	0.002	−0.002	0.057
	(0.003)	(0.002)	(0.020)	(0.003)	(0.003)	(0.021)	(0.005)	(0.005)	(0.042)
$Choc_{t-1}$	0.017***	0.012***	0.047**	0.016***	0.010***	0.035	−0.0004	0.00000	0.078*
	(0.003)	(0.002)	(0.021)	(0.003)	(0.003)	(0.022)	(0.006)	(0.005)	(0.043)
$Choc_{t-2}$	0.013***	0.010***	0.054**	0.013***	0.010***	0.045*	0.005	0.003	0.082*
	(0.003)	(0.003)	(0.023)	(0.003)	(0.003)	(0.024)	(0.006)	(0.006)	(0.047)
$Choc_{t-3}$	0.004	0.004	0.037	0.005	0.005	0.026	−0.003	−0.002	0.036
	(0.003)	(0.003)	(0.023)	(0.003)	(0.003)	(0.024)	(0.006)	(0.005)	(0.049)
$Choc_{t-4}$	0.003	0.0002	0.023	0.002	−0.001	0.014	−0.002	−0.004	−0.033
	(0.003)	(0.003)	(0.024)	(0.003)	(0.003)	(0.025)	(0.007)	(0.006)	(0.051)
$Choc_{t-5}$	0.010***	0.004	0.006	0.011***	0.004	−0.003	0.017**	0.006	−0.042
	(0.003)	(0.003)	(0.025)	(0.004)	(0.003)	(0.026)	(0.007)	(0.006)	(0.051)
$Choc_{t-6}$	0.007**	0.005	−0.027	0.007*	0.004	−0.038	0.009	0.007	−0.063
	(0.003)	(0.003)	(0.027)	(0.004)	(0.003)	(0.028)	(0.007)	(0.006)	(0.054)
$Choc_{t-7}$	0.006	0.004	−0.015	0.005	0.004	−0.027	0.008	0.010	−0.025
	(0.004)	(0.003)	(0.027)	(0.004)	(0.004)	(0.028)	(0.008)	(0.007)	(0.054)
$Choc_{t-8}$	0.002	0.00004	−0.038	0.001	−0.001	−0.051*	0.008	0.003	−0.024
	(0.004)	(0.004)	(0.028)	(0.004)	(0.004)	(0.029)	(0.008)	(0.007)	(0.054)
$Choc_{t-9}$	0.0001	−0.002	−0.056**	0.001	−0.001	−0.064**	0.005	0.002	−0.054
	(0.004)	(0.004)	(0.028)	(0.004)	(0.004)	(0.029)	(0.007)	(0.006)	(0.054)
$Choc_{t-10}$	0.003	0.003	−0.020	0.004	0.003	−0.029	0.007	0.010	0.011
	(0.004)	(0.004)	(0.028)	(0.004)	(0.004)	(0.030)	(0.008)	(0.007)	(0.051)
Observations	415,314	415,314	415,314	393,915	393,915	393,915	259,853	259,853	259,853
R^2	0.186	0.234	0.010	0.187	0.236	0.010	0.174	0.222	0.010

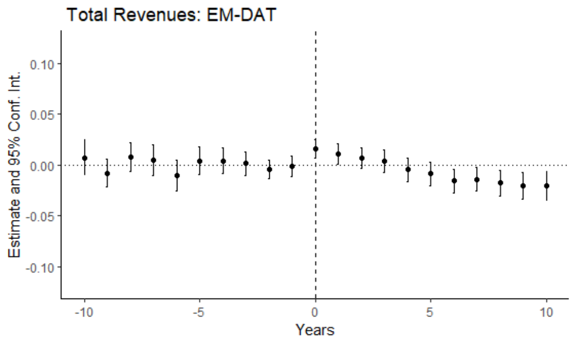
Note: p<0.1; p<0.05; p<0.01; All models control for financial characteristics (local tax and grant revenues), political factors (years before elections), institutional features (type of intermunicipal cooperation), socio-economic factors (median income and percentage of unemployed), and sociodemographic aspects (population size, percentage of youth, and percentage of elderly), as well as time and municipal fixed effects. Standard errors of the estimated coefficients (in parentheses) are corrected for clustered heteroscedasticity at the municipal level.

Figure 11: Effect of a MAJOR natural disaster on the main budget accounts

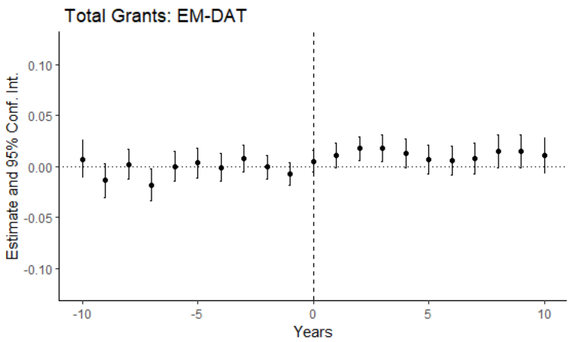
(a) Expenditures



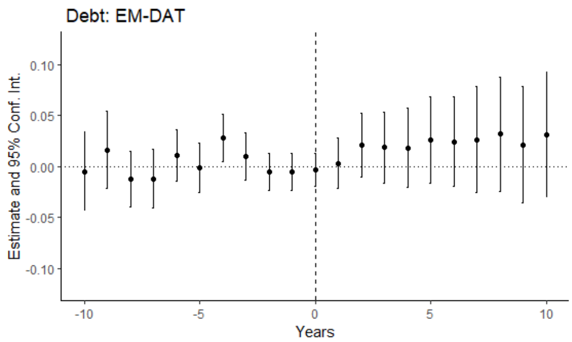
(b) Revenues



(c) Grants



(d) Debt



Note: Estimation of the effect of a major natural disaster on the budgetary accounts of French municipalities with with robust standard errors, using a staggered difference in difference event study methodology. The control variables consist of municipal budget elements, and municipal characteristics controls.