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JEL codes:
H72, Q54, R50

Working Paper

Municipalities' budgetary response to natural disasters

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May 20, 2022

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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. We aim to understand how municipalities adjust their expenditures and revenues during post-shock management. We investigate whether municipalities are able to recover from natural disasters and to what extent they are resilient to shocks. On the other hand, we question risk prevention policies. We examine whether prevention strategies allow for a better crisis management.

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).

A recent part of this literature on the impact of natural disasters on local government finances uses a different method than a fixed-effect panel analysis. Indeed, Miao, Chen, et al. (2020) use a dynamic panel model (PVAR) to estimate the impact of natural hazards on the budgets of Chinese provinces. They show that provincial expenditures and intergovernmental grants increase while there is little effect on tax revenues. Similarly, Panwar and Sen (2020) analyze the dynamic response of Indian local governments and show long-run effects, notably on expenditures.At the U.S. state level, Miao, Hou, et al. (2018) show that post-disaster spending is mainly funded by federal grants, which would disincentivize states to invest in prevention.

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, we analyze the causal link of natural shocks on different local accounts. We use two different estimation methods to better understand the causal impact of disasters on different types of accounts and also to analyze the dynamics of these events. This research provides new evidence of the increase in total expenditures of municipalities due to the occurrence of a natural disaster. We also observe persistent effects over 10 years. The novelty of this study is that it focuses on several types of accounts. We 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. We show that following a climatic shock, municipalities increase their expenditures over the long term, particularly capital expenditures partly to finance new investments. We also show that municipalities react to natural disasters by significantly increasing their debt, and therefore that upper governments do not offer comprehensive insurance against unexpected events.

Our study also questions effectiveness of natural disaster prevention. On the one hand, the public finance theoretical literature on prevention focuses on relationships between different levels of government. In the case of a natural disaster, the central government provides insurance to the other levels of government through grants (Wildasin 2008). However, this insurance is a kind of disincentive for local governments to protect themselves against risks. Ex-post

strategies are mainly the responsibility of the central government, while ex-ante policies are the responsibility of the affected level of government. Theoretical models on this subject show that local governments have an incentive to underinvest in risk protection when the central government offers full insurance. This means that when the loss due to risk is shared between levels of government, risk-averse regions are willing to reduce their investment in protection. (Goodspeed and Haughwout 2012 ; Lohse and Robledo 2013 ; Turati and Buzzacchi 2014). Authors have sought solutions to this underinvestment problem. Turati and Buzzacchi (2014), question the role of private insurers, showing that under certain conditions private insurance can improve social welfare. On the other hand, Lohse and Robledo (2013) propose to institute fixed rather than variable transfers from the central government, in order to induce local governments to exercise an optimal level of protective investment.

On the other hand, the empirical literature on natural hazard prevention has shown that ex-ante strategies are effective in mitigating damage to households in terms of housing, poverty or agriculture (Owens et al. 2003 ; Skoufias 2003 ; Healy and Malhotra 2009). However, few empirical studies have examined the effect of prevention policy on local government. This study seeks to understand whether ex-ante disaster prevention policies have an impact on the accounts and budgetary decisions of municipalities. Our results show that municipalities that have a natural hazard prevention plan before the shock have a much smaller effect on their budget than others. We note that municipalities that had not done any prevention have increased expenses in the long term, while municipalities with an ex-ante program are not impacted in term of expenditure and debt.

The rest of this article is structured as follows. The second section describes the French institutional context, in terms of natural disasters and their definition, as well as the role of municipalities in their disaster management, the grants they can receive and the prevention plans they can implement. Section 3 presents the data and descriptive analysis of natural disasters and the accounts of municipalities. Section 4 presents the econometric models and identification strategies. Section 5 is devoted to the results, first in relation to the main accounts, then to the sub-accounts. Before turning to the risk prevention issues. The last section concludes.

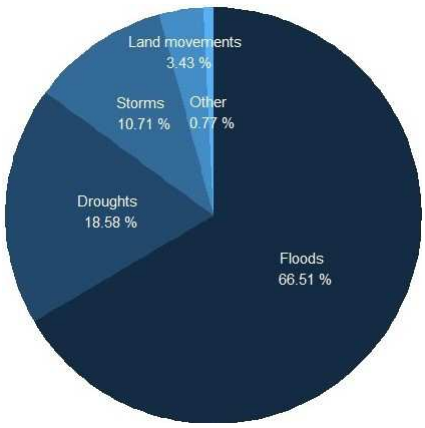
2 Institutional context

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



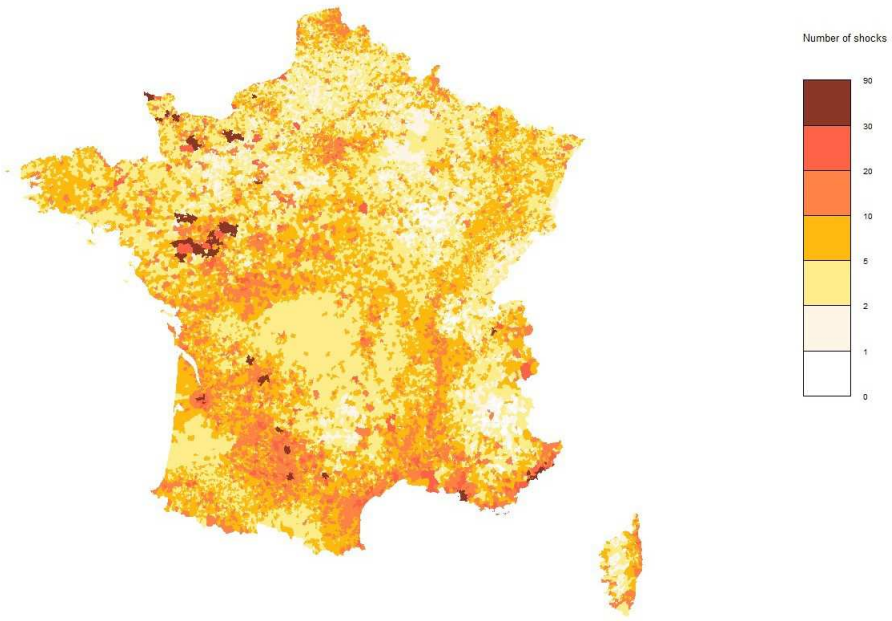
Share of Natural Disaster by type since 1982. This figure shows the share of natural disasters that occurred between 1982 and 2020 at the municipal level by type of shock. The four main categories are floods, droughts, storms and land movements, from the darkest to the lightest color. *Source* : Data 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. We 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, we 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, we 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 topical in France as a new law on compensation for natural disasters has been enacted in December 2021, to make the procedures more transparent

Figure 2: Number of occurrences of natural disasters since 1982

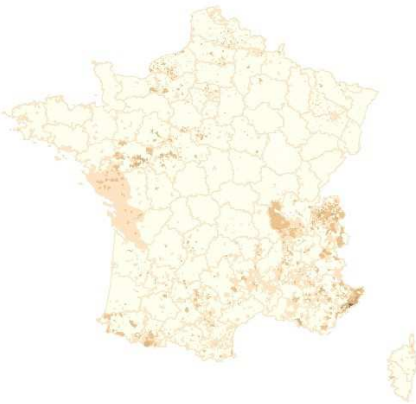


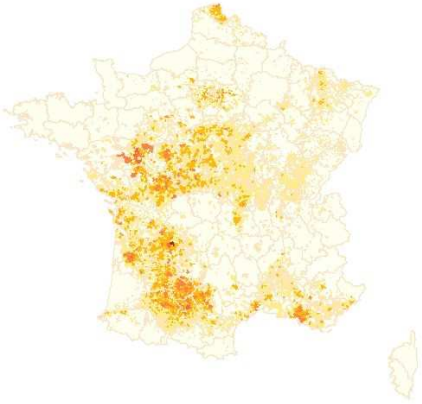
(a) Number of floods

(b) Number of storms

(c) Number of land movements

(d) Number of droughts





Number of occurences of natural disasters since 1982. This map shows the total number of natural disasters that occurred between 1982 and 2020 at the municipal level. The darkest color indicates the municipalities that have been most affected by shocks in the last 40 years, while the lightest color indicates the municipalities that have not suffered any natural disaster. *Source* : Data on natural disasters were provided by the Ministry of Ecology. The cartographic data come from the OpenStreetMap cartographic database constituted from the cadastre made available by the DGFiP (General Directorate of Public Finances).

and efficient. The main changes are: the inclusion in the law of the role of the interministerial commission that carries out annual evaluations and declarations on the reference systems used to evaluate the abnormal intensity of natural phenomena. In addition, a national consultative commission on natural disasters has been created with the objective of re-evaluating the criteria for natural disasters, as well as a group of referents to help municipalities with administrative procedures. Finally, the deadline for declaring a disaster is extended to 2 years and the deadline for reimbursing victims is shortened[1].

2.2 Administrative organization: governments' roles and grants

This study focuses on the French case, which requires particular 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. Indeed, when a natural disaster exceeds the limits of the municipality, the county prefect takes charge of the crisis management instead of the mayor. 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, 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%), loans (20%) or by their own cash flow. However, it is not easy to determine which type of expenditure (e.g security, repair or prevention) is linked to which type of account, current or

[1] Law No. 2021-1837 of December 28, 2021 relating to compensation for natural disasters

investment account.

For costs related to the damage caused by the disaster, municipalities may be assisted in 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 for these (Maurey 2019).

2.3 Prevention strategies : Natural Hazard Prevention Plan

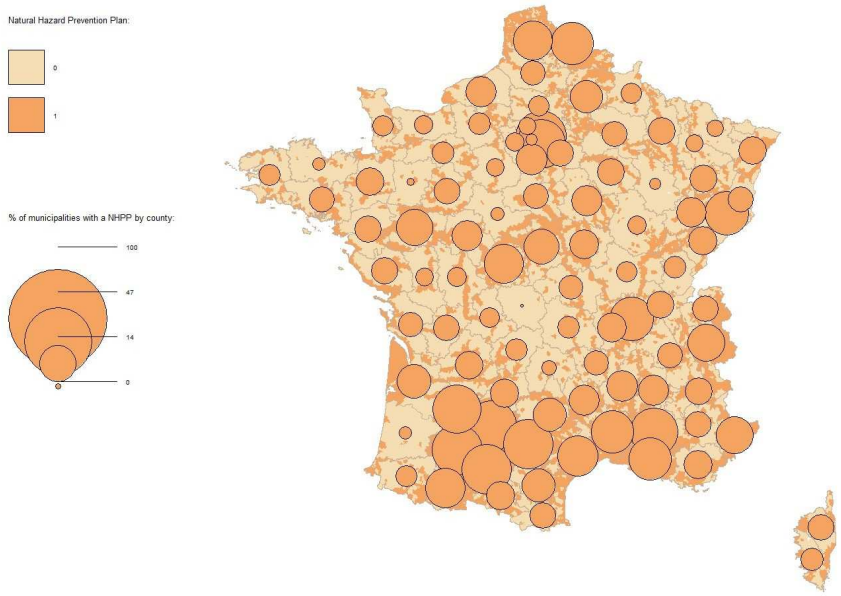
The Natural Hazard Prevention Plans (NHPP i.e Plan de Prévention des risques Naturels) are important tools for risk prevention by the central government. This kind of prevention strategy aim to delimit the zones directly exposed to risks and other zones which are not directly exposed but where certain occupations or uses could aggravate the risks[5]. These plans regulate the use of land in areas exposed to hazards. The natural hasard prevention plans are centralized procedures managed by the prefect, the local authorities are consulted for their opinion[6]. The application of the prevention plan is immediate and mandatory (Scarwell and Laganier 2017). The plan can impose prohibitions, technical requirements, studies and works to protect against risks. The aim is to reduce the probability of occurrence of the dangerous phenomenon. The application of a NHPP therefore generates costs for municipalities. This plan defines rules relating to public networks and infrastructures to facilitate evacuation measures or emergency intervention, moreover the plan can prescribe measures for the maintenance of spaces, the realization or acquisition, management and maintenance in condition of works and equipment[7]. For example, watercourse development work can be prescribed to prevent flooding.

Within the framework of a NHPP, municipalities can request a grant for these studies and works prescribed by the plan or for finance information campaigns on climatic risks. This grant comes from the Barnier fund i.e (fund for the prevention of major natural risks) and can only

[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)
[5]article L.562-1 II of the environmental code
[6]article L. and R.562-1 of the environmental code
[7]article R.562-4 of the environmental code

be awarded to municipalities covered by a Natural Hasard Prevention Plan. The grant does not cover the entire cost, it can cover up to 50 % of the expenses[8]. In extreme cases, the fund of prevention of natural risks allows to compensate the expropriations of properties exposed to major risks.

Figure 3: Natural Hazard Prevention Plan in 2020



Natural Hazard Prevention Plan in 2020. This map shows the total number of approuved Natural Hazard Prevention Plan at the municipal level and at the county level. The darkest color indicates the municipalities that have a prevention plan in 2020, while the lightest color indicates the municipalities that do not have any NHPP. This map consider all the natural hasard prevention plans that have been approved since 1982. *Source* : Data on Natural Hazard Prevention Plan were provided by the Ministry of Ecology. The cartographic data come from the OpenStreetMap cartographic database constituted from the cadastre made available by the DGFiP (General Directorate of Public Finances).

Figure 3 shows the distribution of the Natural Hasard Prevention Plans on the territory, thus a third of the municipalities are subject to a protection plan in 2020. It should be noted that among the municipalities subject to a prevention plan, 88% created it after the occurrence of a natural disaster. On the other hand, 60 % of municipalities that have been exposed to a natural disaster do not have a NHPP. The majority of these municipalities that do not have a prevention plan have faced a low number of shocks. We observe that as the number of shocks occurring in a municipality increases, the proportion of municipalities without a NHPP decreases. In the same way, the proportion of municipalities with a prevention strategy increases with the number of shocks. This raises questions about the impact of the repetition of a shock on municipalities' behavior.

A Natural Hasard Prevention Plan is a measure imposed by the central government that generates additional costs for municipalities, in addition it aims to prevent and limit the impact

[8]article L561-3 of the environmental code

of natural disasters, through studies and works that it imposes. Nevertheless, these plans allow the municipalities to be aware of the risks they are exposed to.

Municipalities therefore have an important role to play in the event of a natural disaster. They are responsible for implementing prevention plans before the crisis, protecting the population during the disaster and restoring normal life as well as ensuring the continuity of public services after the shock. These institutional realities lead us to reflect on the consequences in the budgetary behavior of municipalities following a shock, which we will analyze using descriptive statistics and econometric models.

3 Data and Descriptive Statistics

3.1 Data

To create the database for this study, which includes 34,393 municipalities between 2000 and 2019, we 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 8 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, as well as the information on the Natural Hasard Prevention Plan. 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.). Data prior to 2000 on the occurrence of natural disasters allows us to create an indicator of risk exposure[9] (Masiero and Santarossa 2020). 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. Moreover, we know the important dates of the natural risk prevention plans by municipality, their date of prescription, application, and abrogation if applicable. 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.

Among the 36,680 French municipalities in 2000, we have chosen to analyze only a part (34,393), in particular we have removed the overseas municipalities that experience natural disasters of a different intensity than those in metropolitan France. Moreover, in order to analyze homogeneous municipalities as much as possible, we implemented a hierarchical cluster analysis

[9]Historical natural disaster experience is measure by en index: $HE_{i,2000} = \sum_{t=1982}^{1999}(Shock_{i,t}/(2000-t)$. This is the sum of the disaster occured before 2000, weighted by the inverse of the number of years passed since the occurrence of the shocks, according to Masiero and Santarossa (2020) methodology.

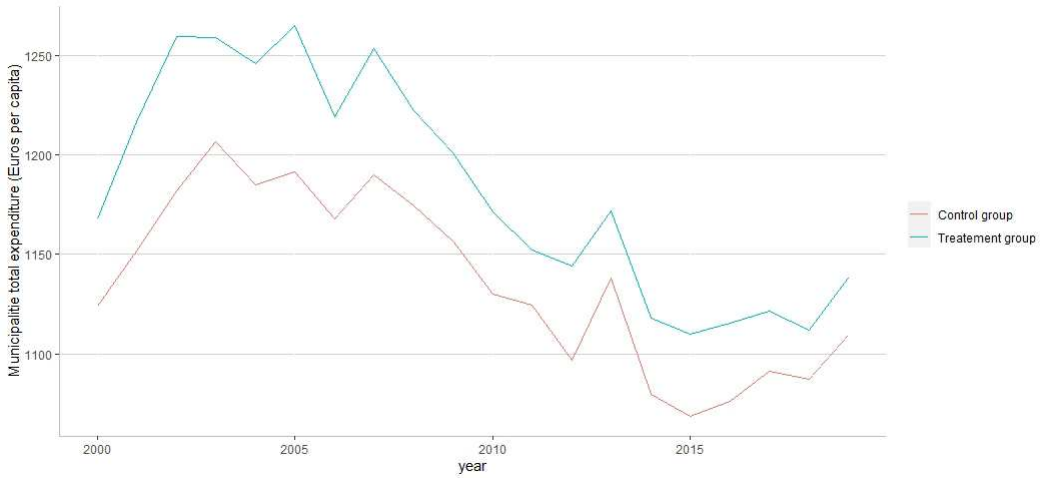
that allowed us to exclude a group of individuals whose characteristics were too different from the others. We notice that budgetary data are in euro per capita and they have been deflated according to the annual consumer price index of INSEE.

3.2 Summary Statistics

In order to understand how a natural disaster impacts the budgetary behavior of municipalities, we first compare municipalities that have experienced a shock between 2000 and 2019, i.e a treatment group and municipalities that have not, the control group. To be included in the treatment group, one must have experienced at least one natural disaster over the period.

Figure 4 shows that there is a difference in total expenditure between municipalities that experienced a shock and those that did not. The municipalities in the treatment group have on average higher expenditures than the municipalities in the control group over the period 2000-2019. We notice that both groups follow similar trends. However, in this first graph, no variable is controlled; we observe all municipalities regardless of their characteristics.

Figure 4: Municipal total expenditures between 2000 and 2019



Municipal total expenditure in euro per capita over time (2000-2019). This figure shows the variation in expenditures of municipalities on average, depending on whether they are in the control or treatment group. The treatment group (blue line) is composed of 22,727 municipalities that have experienced at least one natural disaster between 2000 and 2019, compared to the control group (red line) which is composed of 11,666 municipalities that have not been impacted. *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.

Table 1 shows the differences between the two groups in detail. It first compares the characteristics of the municipalities in the control group with those of the treated municipalities in the pre-shock period, and then compares the treated municipalities in the pre- and post-treatment periods. We observe that before and after a natural disaster, the characteristics of the municipalities vary. Indeed, the budget tends to increase after the shock. On the other hand, we also observe differences between the control group and the treatment group in the period before

Table 1: Descriptive statistics - Municipalities' characteristics per capita

	Control Group	Treatement Group	
		Pre-shock period	Post-shock period
Municipal Expenditure			
Total Expenditure	1136.62	1195.35 ***	1176.84 ***
	(889.01)	(887.96)	(776.48)
Current Expenditure	639.15	670.89 ***	704.74 ***
	(370.94)	(372.56)	(389.13)
Investment Expenditure	497.47	524.46 ***	472.10 ***
	(687.13)	(692.18)	(552.86)
Municipal Revenues			
Total Revenues	1338.40	1385.95 ***	1348.44 ***
	(996.39)	(979.83)	(862.79)
Current Revenues	836.38	856.90 ***	872.59 ***
	(474.54)	(455.54)	(454.78)
Local taxes	250.52	280.03 ***	309.74 ***
	(189.23)	(208.70)	(216.74)
Operating Grant	209.46	215.18 ***	202.78 ***
	(126.15)	(118.26)	(112.17)
Investment Revenues	502.02	529.05 ***	475.85 ***
	(696.45)	(701.28)	(568.03)
Cash flow	205.58	191.79 ***	180.25 ***
	(246.33)	(202.81)	(180.73)
Debt	205.58	191.79 ***	180.25 ***
	(626.78)	(622.57)	(640.34)
Municipal Characteristics			
Median Income	18,489.14	16,547.53 ***	19,159.76 ***
	(4342.87)	(3810.51)	(4059.14)
Population	678.49	1322.40 ***	2726.66 ***
	(2785.27)	(4504.02)	(13050.33)
% Young (0-20 years)	24.43	24.22 ***	23.75 ***
	(7.93)	(6.82)	(6.42)
% Old (>65 years)	19.11	19.29 ***	20.08 ***
	(8.92)	(8.00)	(8.09)
% unemployment	8.06	8.48 ***	9.29 ***
	(7.60)	(6.15)	(6.78)
Natural Hasard Prevention Plan	12.60 %	16.04%	40.34%
Municipalities	11,666	20,411	22,727
Observations	233,320	155,567	298,973

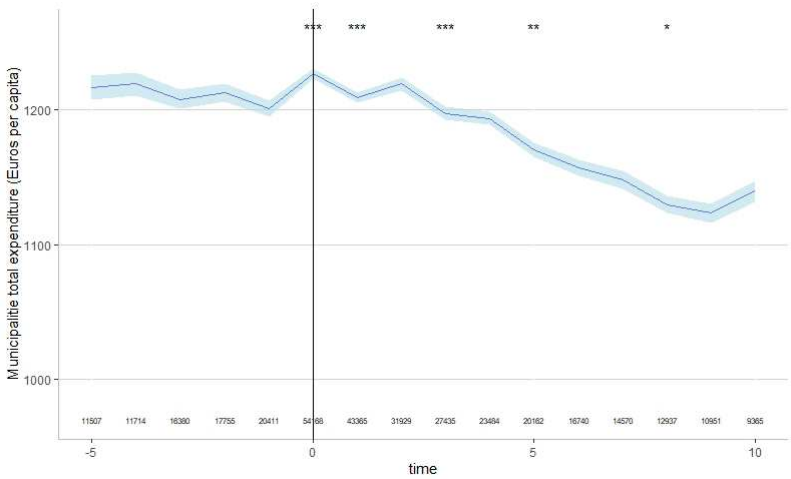
Note: This table shows the average characterisitcs of municipalities affected by a natural disaster (treatment group) in two period : before the shock, i.e the pre-treatement period and after the shock. The treated municipalities in pre-shock period are compared to the mean characteristics of the control group, i.e municipalities that have not faced a disaster (column 1 and 2). Stars in columnn 2 indicate significance levels of t-test on mean differences between column 1 and 2. Then, the we compare the treatment group at both period, before and after the shock (colum 2 and 3). Stars in columnn 3 indicate significance levels of t test on mean differences between column 2 and 3. Standard deviations are in parentheses. *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).

***p<0.001 **p<0.01 *p<0.05

the shock. These differences show that our two groups are not easily comparable. Indeed, the French municipalities are numerous but also very heterogeneous, whether in terms of public finance or demographic and socio-economic characteristics (see Table 7 and 8 in the Appendix).

The following figure 5 shows us in more detail the budgetary responses of municipalities following a shock. Here, we observe only those municipalities that have experienced at least one natural disaster, with the date of the shock(s) normalized to 0. The figure shows a significant increase in expenditures at the time of the shock and then a return to the pre-shock amount the following year, and then we see a decline.

Figure 5: Average change in total expenditures for municipalities affected by a disaster



Municipal total expenditure in euro per capita according to the time of the natural disaster(s). These figures compare the average per capita local gouvernment expenditure before and after the occurence of a natural disaster which occurs at time zero. This group is the treatment group (blue line) composed of 22,727 municipalities that have experienced at least one natural disaster between 2000 and 2019. Positive values on the x-axis indicate years after the shock, while negative values indicate years before. The stars at the top of each figure indicate the significance according to the t-stat of the difference with the previous year. *p<0.1; **p<0.05; ***p<0.01 *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.

These elements give us clues about the impact of natural disasters on municipal spending. An econometric approach can allow us to understand the causal relationship between a shock and the accounts of municipalities. The next section proposes two econometric models to analyze these phenomena.

4 Econometric approaches

4.1 Model specification

To complete our descriptive analysis we use an econometric model inspired by Gallagher (2014), Berset and Schelker (2020), Masiero and Santarossa (2020) and Liao and Kousky (2022). 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 us to build the following model:

$$Y_{i,t} = \sum_{j=0}^{10} \beta_{\tau-j} Shock_{i,\tau-j} + X_{i,t}\gamma + \mu_i + \theta_t + \varepsilon_{i,t} \tag{1}$$

The dependent variable $Y_{i,t}$ is the logarithm[10] of one municipality's account, which can be total expenditures, revenues, grants or other subaccounts. Our main variable of interest is the variable $Shock_{i,\tau-j}$ which represents the natural disaster, it is a dummy variable equal to 1 when the disaster occurs, i.e. $Shock_{i,\tau} = 1$ the year that municipality i is affected by a natural disaster and $Shock_{i,\tau-1} = 1$ if municipality i has been affected by a natural disaster last year. We 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.

4.2 Estimation strategy and endogeneity issues

In order to estimate the model proposed for this analysis several estimators can be used. First of all, a pooled OLS model has the advantage that it allows us to control for time-invariant environmental situations such as the geographical position of the municipality, whether it is in the mountains or on the coast. However, this estimator does not take into account the temporal dependence between the observations and does not control for unobserved time-invariant heterogeneity like a fixed effect model. A random effects model has the advantage of providing an estimate that is both consistent and efficient when the model assumptions are satisfied. It also controls for time-invariant observed factors. However, the assumptions of this model are

[10] 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.

demanding and the estimate is spurious if the assumption of independence of time-invariant errors is violated. The model chosen is therefore a fixed effect regression which allows to fight against the unobserved time-invariant heterogeneity. We also support this choice by performing pooling and Hausman tests. The choice of the fixed effect estimator is the within estimator, which allows us to lose less information than a first difference or between estimator. The two-way fixed effect model is also the most commonly used in the event study literature. Moreover, White's robust covariance matrix and municipal cluster allows us to control for heteroscedasticity and serial correlation.

We can now turn our attention to endogeneity issues. The first problem is raised by Masiero and Santarossa (2020) who document that some explanatory variables such as the grants received from the central government could be influenced by the expenditures of municipalities. In this case, we face a reverse causality problem, which would bias a pooled OLS estimator. However, a fixed-effects within estimator controls for time-invariant factors that could lead to endogeneity in the grants.

The second problem could result from that the shock can also impact some regressors. Indeed, we can suppose that a natural disaster has an effect on the income of the inhabitants for example. In this case, the shock coefficient may be biased. To test this endogeneity problem we perform the estimation with and without the control variables. We observe no significant difference between the two estimates, they both go in the same direction (table **??** in appendix).

Third, a confounding factor could bias the estimate. It is possible that an unobserved factor could have an effect both on the occurrence of a natural disaster and on the expenditures of a municipality. 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 be a municipal expense. In the opposite case, we can imagine that a municipality wishing to limit its expenses makes the choice to take care less regularly of its river installations, then that could impact the risk of disaster. To limit this endogeneity problem, we could check the existence of a risk prevention plan in the municipality. Indeed, the objective of a NHPP is largely to raise awareness of the disaster risks in a municipality and to delimit the potentially risky areas in order to limit construction in particular. We therefore add prevention plans as a control variable. It is a dichotomous variable equal to 0 if there is no prevention plan and equal to 1 when a prevention plan is created and the years when it is in place. The addition of this control variable does not change the results presented in the following section.
In addition, we ensure the robustness of the results by defining different treatment assignments based on the duration or type of disaster experienced by the municipality. Moreover, we also test the sensitivities by considering only a part of the municipalities according to the timing and number of shocks they have suffered (see section 7.2).

Nevertheless, the two-way fixed effect (TWFE) model is questioned in the recent literature (Sun and Abraham (2020), Chaisemartin and D'Haultfoeuille (2022)). It is shown that the estimated coefficients could be contaminated by the effects of other periods. Therefore, in

addition to the TWFE model, we draw on another part of the literature on the impact of natural disasters on public expenditures using a dynamic panel model (PVAR).

4.3 Dynamic 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. We estimate the following empirical specification :

$$Y_{i,t} = \alpha_0 + \alpha Y_{i,t-1} + \sum_{j=0}^{5} \beta_{\tau-j} Shock_{i,\tau-j} + \mu_i + \theta_t + \varepsilon_{i,t} \tag{2}$$

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 ($j = 0, 1, 2, 3, 4, 5$). We 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 we 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 $t-3$. We 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. We 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. We 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 Result

5.1 Two analyses for main-accounts

5.1.1 Two-Ways Fixed Effect model

The table 2 reports the results of the regressions based on the model of the equation (1). 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 in columns 1, 2, 3 and 4 respectively.

Table 2: Impact of Natural disaster on local gouvernment main accounts

	Fixed Effect model - Within Estimator			
	Total Expenditures	Total Revenues	Total Grants	Debt
Shock_{τ}	0.007***	0.007***	−0.004	0.033**
	(0.002)	(0.002)	(0.006)	(0.014)
$\text{Shock}_{\tau-1}$	0.007***	0.004**	0.005	0.039***
	(0.002)	(0.002)	(0.006)	(0.015)
$\text{Shock}_{\tau-2}$	0.006***	0.004*	0.018**	0.041**
	(0.002)	(0.002)	(0.007)	(0.016)
$\text{Shock}_{\tau-3}$	0.005**	0.003	0.017***	0.038**
	(0.002)	(0.002)	(0.006)	(0.017)
$\text{Shock}_{\tau-4}$	0.004	0.001	0.015***	0.033*
	(0.002)	(0.002)	(0.005)	(0.018)
$\text{Shock}_{\tau-5}$	0.003	0.001	0.009	0.024
	(0.002)	(0.002)	(0.006)	(0.018)
$\text{Shock}_{\tau-6}$	0.002	−0.002	0.004	0.001
	(0.003)	(0.002)	(0.007)	(0.020)
$\text{Shock}_{\tau-7}$	0.002	0.003	0.006	0.001
	(0.003)	(0.003)	(0.008)	(0.020)
$\text{Shock}_{\tau-8}$	−0.003	0.001	0.005	−0.021
	(0.003)	(0.003)	(0.008)	(0.021)
$\text{Shock}_{\tau-9}$	0.001	−0.001	0.008	−0.028
	(0.003)	(0.003)	(0.009)	(0.021)
$\text{Shock}_{\tau-10}$	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
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 and from grants), 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 and clusterised at municipal level Standard errors in parentheses, using White's covariance matrix.

Moreover, as the dependent variable is log-transformed we can interpret the coefficients in percentages such as $(\exp^{\widehat{\beta}} - 1) \times 100$. The first observation is a significant increase in total expenditures in the year of the natural disaster[11], as well as in the 3 years following the shock. The impact of the natural disaster at the time of the shock is about 0.7%, which corresponds to an increase of 820 euros in average per municipality per inhabitant. Column two shows the fixed-effect estimates on the logartithm of total revenues of municipalities. We note a significant and increase in revenues after a natural disaster. We can see an increase of 0.7% in revenues in the year of the shock and up to 2 years after the disaster. These results show that the shock has a direct effect on revenues, which is not persitent over time. The third column looks at the estimates on the logarithm of total grants, i.e sum of operating grant and investment grants. These results show a significant increase in subsidies from the second post-disaster year to the forth year. This shows that the increase in total revenues at the event of the disaster is not due to a significant increase in grants from higher governments. Furthermore, the increase in grants between $\tau - 2$ and $\tau - 4$ does not cause a significant increase in total revenues. Finally, the 4th column shows the estimates for the debt. This column shows an increase of 3.3% of debt at the time of natural disaster. This is a strong impact that persists up to 4 years after the shock.

These results are consistent with the literature that shows an increase in expenditures, revenues and debt. However, 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 Dynamic analysis : PVAR model

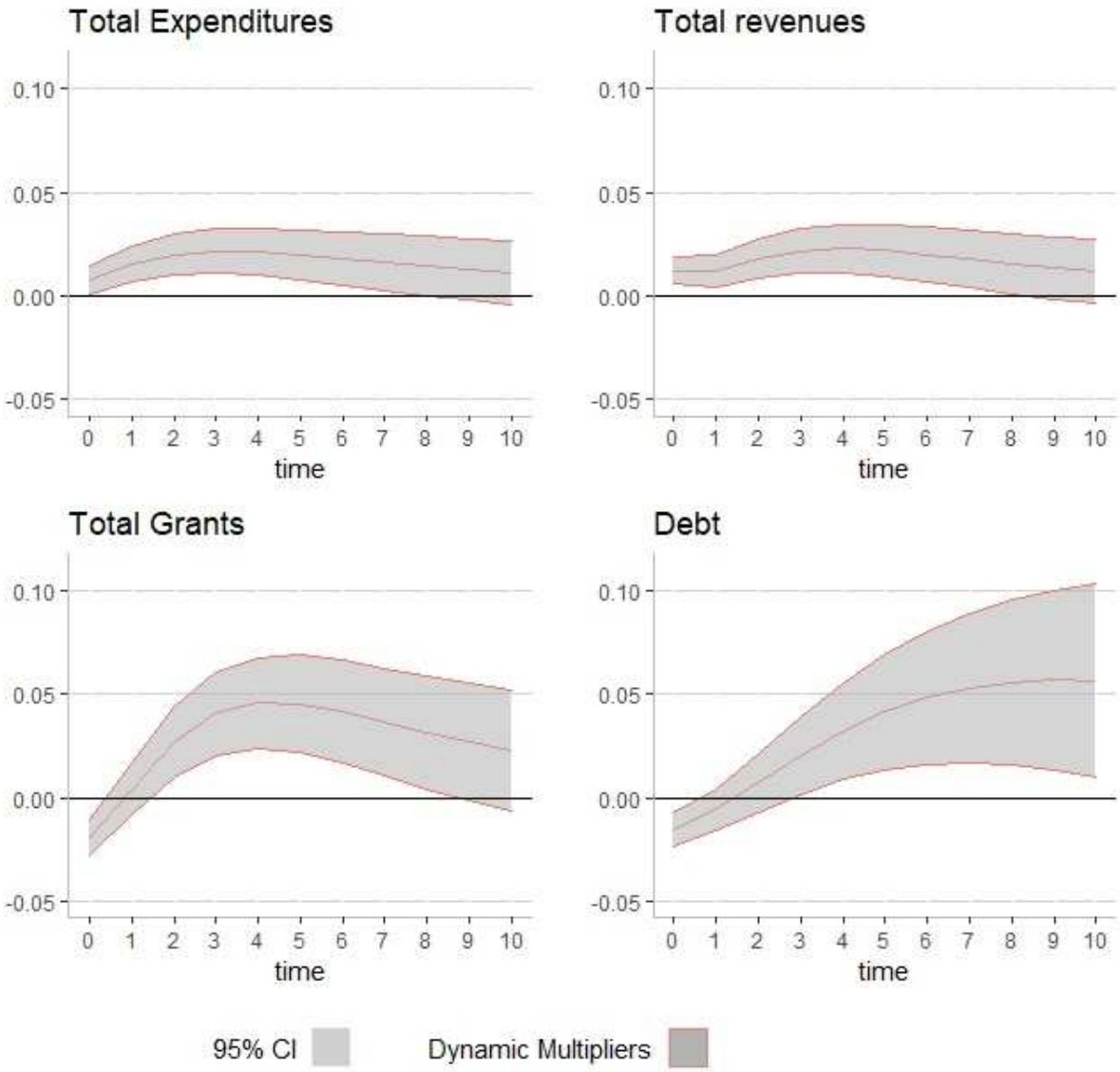
We now compare the results of the panel two ways fixed effect method with the dynamic panel method: panel vector autoregressive model. The figure 6 shows the dynamic responses of the PVAR model estimate of equation (2) and the following table presents the point estimates of the DMFs.

The estimated points represent the variation of the different variables following the occurrence of a natural disaster. As expected, the figure 6 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 TWFE estimate. This increase is significant in the 8 years after the shock, showing persistence in this impact. Subsequently, we can similarly see a significant increase in total revenue at the time of the shock, growing until t-4 and then decreasing over time (bottom left). Considering the grants (top right), we observe a significant decrease at the time of the shock, which was also the case in the previous estimate although not significant. This is followed by a significant rise in this increase until 4 years after the shock, before a decrease. 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.

[11] Year τ represents the year when the shock occurred, year $\tau - 1$ is the following year and so on until $\tau - 10$ which represents the 10th year after the occurrence of the disaster.

If a municipality experiences several natural disasters, the count starts again with each new shock.

Figure 6: Dynamic Response of main accounts



Dynamic Response of main accounts to a natural disaster. 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.

Finally, looking at the response of municipal debt (bottom right) reveals a decrease at the time of the shock, which is the major difference with the results of the TWFE estimate. Thereafter, we 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. However, we wonder about the negative and significant impact of the shock on the debt in the year of the shock, and the analysis of the sub-accounts will be able to provide some insight.

These results seem to be consistent in the majority with the TWFE estimate, but show us more precisely the dynamics of the responses and seem to indicate a persistence in the post-disaster reactions. Indeed, with this estimate we find that municipalities experience an increase in expenditures up to 8 years after the disaster and up to 10 years for the debt.

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.

Having seen the impact of a natural disaster on the main accounts, we will now look at sub-accounts i.e. the expenditure and revenue accounts less aggregated, in order to understand what types of expenditures and revenues are affected by the shock more precisely. We wonder if the increase in expenditures comes from an increase in expenditure for investment, reconstruction or on the contrary whether it is for current expenditure. On the other hand, we would like to understand if the increase on the revenue side is due to an increase in tax revenue or borrowing or both.

5.2 Sub-accounts : expenditures and revenues

5.2.1 Type of expenditure

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.

The results of the main accounts showed that expenditures increased after the occurrence of a shock, as well as debt. These results made us wonder about the types of expenditure

that are involved in this increase. For this reason, Table 4 shows fixed-effect estimates on the logarithm of 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.

The table 4 is composed of two parts : the first concerns current expenditure, with column 1 representing the estimates on the logarithm of salary expenditure and column 2 that of current purchases. The second part of the table concerns investment expenditures, with column 3 for capital expenditures and column 4 for loan repayments.

If we look at current expenditure, the table of sub-accounts shows us that personnel costs increase significantly in year after the shock and in the 6th year following the disaster. This indicates that following a natural disaster, a municipality needs more personnel expenses, in terms of euro per municipalities per inhabitants, the impact on salary expenses is about 190 euros per inhabitant the year after the disaster. In contrast, the second column shows us that current spending decreases significantly in the 8th year after the shock, but we do not observe a significant effect earlier. The effect of the shock on the current accounts seems to be quite small, let us now consider the second part of the table with the investment accounts The column 3 of the the table 4 shows that capital expenditures increase by 3.0%, 2.6% and 2.4% the 3 years after the disaster. It should be noted that capital expenditures considered here are only for the acquisition of new capital, not for repair costs. Which means that in $\tau - 1$, $\tau - 2$ and $\tau - 3$, the two years following the disaster, municipalities are able to finance new investments. Concerning loan repayments, we observe a significant increase from the year of the shock up to 9 years after the natural disaster. This increase suggests an increase in borrowing after the shock, but it seems surprising that loan repayments increase immediately after the shock.

These estimates show that the increase in municipal expenditures following a shock is mainly due to an increase in investment expenditures, both for capital purposes and for borrowing. In the analysis of the main accounts we observed an increase in expenditures from the year of the shock, we assume that this increase is due to other types of sub-accounts that our disaggregation does not allow us to observe. This analysis of the sub-accounts allows us to better understand the choices made by municipalities following a natural disaster. However, we would need more detailed accounts to be able to push our analysis even further. We will now examine the the impact of a natural disaster on different revenus.

5.2.2 Impact of natural disaster on revenues

We 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 the accounts of the municipalities, operating grants and tax revenues are considered as current revenues (first part of the table 5, columns 1 and 2) and investment grants and loans are investment 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.

(second part of the table 5, columns 3 and 4). First, regarding tax revenues, there is a significant increase from the second year after the shock to the 10th year. The second year after the disaster the impact is around 1.1% which corresponds to 313 euros per inhabitant. 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, we see that operating and investment grants (columns 2 and 3) react differently to a shock. We observe in column 3 that investment grants are impacted immediatly when a natural disaster occurs such that the impact is around 5.6%. We notice a significant increase of investment grants from the year of the shock until 3 years after it. We assume that investment grants would be used to repair disaster-related damage first and allows the development of new investment projects in a second time. On the other hand, operating grants increase the 5th year to the 10th year, and decrease at the time of the shock and the year after. 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). Finally, column 4 estimating the logarithm of municipal loans shows a significant increase the second year following the disaster. On the other hand, we observe a significant decrease the 6th year to 9th year. This means that the municipalities take more new loans after the disaster, but they reduce their loans after the 6th year.

These different results show that natural disasters have a significant and persistent effect on local government spending. It seems that municipalities take several years to recover from a natural disaster and they use all the levers at their disposal to compensate for the increased expenses. The question now is whether prevention can limit these effects. Natural hazard prevention plans may have a role to play in budgetary decisions, and investment in a prevention plan may lead to better management of one's expenses in the event of a disaster. Disaster awareness could lead to better management and perhaps faster recovery from a disaster. It seems that municipalities take several years to recover from a natural disaster and they use all the levers at their disposal to compensate for the increased expenses.

5.3 The role of prevention plan

We are interested in the role of prevention strategies in municipal budgeting behavior in response to natural disasters. As we saw in section 2.3, the Natural Hasard Prevention Plan (NHPP) are plans whose aim is to encourage local jurisdictions to invest in risk prevention. These plans allow municipalities to benefit from funds to adapt territories subject to risks and to inform their population. We assume that municipalities covered by a prevention plan are aware of the risk they are exposed to, whereas municipalities without a plan are unaware or less aware. We assume that being aware of the risk may generate different behaviors compared to other municipalities, on the one hand because they are better prepared through prevention, but also because they have been able to delimit the dangerous areas and limit the infrastructures in these areas that can limit the impact of the disaster.

For this purpose, we choose to divide our municipalities in two samples, the first one contains the municipalities subject to a NHPP since a date prior to the natural disaster and on the other hand the municipalities that did not have a NHPP before the shock. However, the municipalities in the second group were able to benefit from a Natural Hazard Prevention Plan after the shock. Among the entire group, municipalities with a pre-shock prevention strategy are in the minority, 5,522 versus 28,871 municipalities without a hazard prevention plan. As in the first part, we analyze the main accounts in the table 6: total expenditure (columns 1 and 2), total revenues (columns 3 and 4), total grants (columns 5 and 6) and debt (columns 7 and 8). The table 6 shows significant differences between the two groups. The estimates in the first two columns, total expenditures, show a significant and persistent increase in these expenditures for municipalities that do not have a pre-disaster prevention strategy. On the other hand, the shock doesn't have any impact on municipalities with a NHPP. These results on total expenditure seem to indicate that prevention plans have a significant effect on the budgetary behavior of post-natural disaster management. While, on the one hand, municipalities without a prevention strategy increase their spending over several years, those that had anticipated the shock have no impact on their expenses. Columns 3 and 4 of Table 6 focus on total revenues. The difference between the two groups is also important. We observe a significant increase in total revenues in the first 3 years after the natural disaster for municipalities without an NHPP. In contrast, for municipalities with a pre-disaster prevention strategy, we observe a significant decrease during the years of the disaster and around the 5th and 6th year. These results show that despite the prevention strategy, natural disasters generate a decrease in revenues, perhaps because of a drop in tax revenue due to the disaster. But, these data do not allow us to disentangle the type of revenues involved. Then, columns 5 and 6 of the table 6 focus on total grants. They show that municipalities without a pre-disaster prevention plan have a significant and persistent increase in their investment expenditure up to 9 years after the shock. On the contrary, municipalities with a NHPP don't see any increase in grants except at the end of the period. The significant increase at the end of the period shows that municipalities that anticipated the shock do not need grants in the short term due to disaster mitigation. This increase can be explained by a demand for funds for new non-urgent investments or to improve their protection strategy. Finally, the last two columns show us the effects on the debt of municipalities. They show us that municipalities that did not anticipate the shock must increase their debt significantly during the 3 years following the shock. While the municipalities that had a prevention strategy do not experience any increase in their debt.

These results show the effectiveness of natural hazard prevention plans. Municipalities without a prevention strategy have an impact for several years after the shock, which shows that they have difficulty recovering from the crisis and absorbing the shock. Crisis management seems more difficult and requires more resources. On the other hand, municipalities with an NHPP have less impact on their expenditures. Prevention seems to have a positive effect on the ability of municipalities to recover from the shock, which offers opportunities in terms of public policy.

Table 6: Impact of natural disasters on local government accounts according to their adherence to a Natural Hasard Prevention Plan.

	Fixed Effect model - Within Estimator							
	Total Expenditure		Total Revenues		Total grants		Debt	
	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP
Shock_{τ}	−0.006	0.010***	−0.007*	0.009***	0.008	−0.003	0.007	0.038**
	(0.004)	(0.002)	(0.004)	(0.002)	(0.007)	(0.003)	(0.032)	(0.015)
$\text{Shock}_{\tau-1}$	0.002	0.007***	−0.001	0.005**	0.012	0.004	0.020	0.042**
	(0.005)	(0.002)	(0.004)	(0.002)	(0.008)	(0.003)	(0.035)	(0.016)
$\text{Shock}_{\tau-2}$	0.002	0.006**	−0.001	0.004**	0.009	0.017***	0.035	0.041**
	(0.005)	(0.002)	(0.005)	(0.002)	(0.008)	(0.003)	(0.038)	(0.018)
$\text{Shock}_{\tau-3}$	−0.003	0.006**	−0.004	0.004*	0.009	0.017***	0.006	0.042**
	(0.005)	(0.002)	(0.005)	(0.002)	(0.009)	(0.004)	(0.040)	(0.019)
$\text{Shock}_{\tau-4}$	0.0003	0.003	−0.001	0.001	0.008	0.015***	0.042	0.030
	(0.006)	(0.003)	(0.006)	(0.002)	(0.011)	(0.004)	(0.042)	(0.019)
$\text{Shock}_{\tau-5}$	−0.006	0.004	−0.012**	0.002	0.010	0.010***	0.034	0.021
	(0.006)	(0.003)	(0.006)	(0.002)	(0.011)	(0.004)	(0.047)	(0.020)
$\text{Shock}_{\tau-6}$	−0.0004	0.002	−0.011*	−0.001	0.003	0.012***	0.007	−0.001
	(0.007)	(0.003)	(0.006)	(0.003)	(0.012)	(0.004)	(0.052)	(0.021)
$\text{Shock}_{\tau-7}$	−0.011	0.003	−0.007	0.004	0.012	0.013***	0.029	−0.005
	(0.007)	(0.003)	(0.007)	(0.003)	(0.012)	(0.004)	(0.055)	(0.022)
$\text{Shock}_{\tau-8}$	−0.001	−0.003	−0.002	0.001	0.018	0.013***	0.0002	−0.025
	(0.008)	(0.003)	(0.008)	(0.003)	(0.012)	(0.005)	(0.058)	(0.022)
$\text{Shock}_{\tau-9}$	−0.013	0.003	−0.006	−0.001	0.036***	0.014***	0.044	−0.039*
	(0.008)	(0.003)	(0.008)	(0.003)	(0.013)	(0.005)	(0.061)	(0.022)
$\text{Shock}_{\tau-10}$	−0.001	0.002	−0.005	0.001	0.029*	0.009	0.055	−0.005
	(0.010)	(0.004)	(0.009)	(0.003)	(0.017)	(0.005)	(0.062)	(0.022)
Observations	103,706	525,538	103,706	525,538	103,706	525,538	103,706	525,538
Municipalities	5,522	28,871	5,522	28,871	5,522	28,871	5,522	28,871
R^2	0.158	0.190	0.194	0.242	0.104	0.108	0.010	0.010
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipalities fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Financial controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Socio-economic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Socio-demographic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Institutional controls	Yes	Yes	Yes	Yes	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.
The sample of municipalities with a NHPP contains only those municipalities that had a natural hazard prevention plan before the occurrence of a natural disaster. In contrast, the municipalities in the "no NHPP" sample are those that did not have a prevention plan before the disaster occurred. However, some of them have put in place a NHPP after the shock.

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. The first robustness check analyse the sensitivity of the results by selecting municipalities with respect to the number of shocks experienced or the history of past shocks. In addition, we analyze the intensity via the duration of natural disasters. Finally, the last check is a test where the treatment concerns only municipalities that have experienced a specific type of shock, such as floods or droughts.

The first test changes the way the treatment is assigned, some municipalities are excluded based on the number of shocks they have experienced. We 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 we exclude municipalities that have experienced a shock after 2015. The results seem to be in line with the baseline results. However, we 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 we look at the sample of municipalities that had never experienced a shock before 2000, we 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.

Second, we choose to measure the treatment based on the duration of the disaster. Indeed we assume that the duration of the shock can be an indicator of its intensity. We 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 we observe that when the disaster lasts one day or less, municipal expenditures are much less affected, except for debt, which increases significantly.

Finally, for the last test, the treatment assignment is based on the type of disaster. We 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 opposite to the baseline results. It appears that municipalities spend less following 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. In addition, we perform a falsification test to ensure that there is no placebo effect. We perform the regressions as for the baseline results by observing the years prior to the shock, to detect a possible effect. The results of this test show that there is no significant effect in the 2 years

preceding the shock. We 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 7.2.

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 we use data from the accounts of French municipalities since 2000 as well as all natural disasters since 1982. 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. The results on the expenses show us this as well. We observe a significant increase in total expenditures from the time of the shock and the following 3 years. This corresponds to the direct costs of the disaster and then to the expenses of reconstruction. The sub-accounts show us that there is a significant increase in spending on new investments in the three years following the shock. In contrast to the findings of Jerch et al. (2020) for U.S. hurricanes. Then we note a decrease in the growth of expenditures, which suggests a shift to the indirect costs of the shock, i.e. the costs of prevention.

In response to these increases in expenditures, we observe that all revenue levers are used. We observe an increase in grants, first of all investment grants that start at the moment of the shock, and then operating grants that are provided afterwards. This increase in grants shows that the central government is supporting the municipalities. We 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 two-year delay after the disaster. This can be explained by the new post-shock investments that have boosted the municipality. On the other hand, we 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 last lever to compensate the additional expenses due to natural disasters is the recourse to

borrowing. Indeed, the results show an increase in borrowing from the second year following the disaster, and a persistent increase in debt. However, if we examine expenditures precisely, we observe an increase in loan repayments at the time of the shock, which is inconsistent with the observed increase in loans in the second year following the disaster. This leads us to assume that local governments are using the natural disaster as an excuse to increase their expenditures in order to perhaps justify more grant applications. If we follow this assumption, then we can assume that local governments are using the shock to slightly over-increase their spending. This interpretation can be linked to the findings of Masiero and Santarossa (2020) , who show that local governments tend to exploit the occurrence of natural disasters to maintain high levels of expenditure. Another possible explanation is that municipalities are trying to reduce their debt at the time of the disaster because they know they will receive grants and will have to increase their debt in the future. This argument is consistent with the decrease in debt that is observed at the time of the disaster

Natural disasters therefore have persistent effects on municipal budgets e.g. up to 10 years of increased debt. This leads to a deterioration of the financial health of the municipality. This shows that the central government does not provide full insurance against shocks. The municipalities have to partly absorb the shock by themselves despite the consequences on their accounts. On the other hand, by focusing on the role of prevention, we note that prevention allows municipalities to effectively mitigate the effect of the disaster in terms of public expenditure. Indeed, our results show that municipalities that had implemented a natural hazard prevention plan did not increase their expenditures and their debt over the long term, unlike the others. This provides evidence of the effectiveness of prevention plans in terms of budget. We clearly observe that municipalities that have taken prevention into account are more efficient in recovering from the disaster and this is reflected in their expenses and their debt. Prevention systems have been shown to be effective in mitigating the effects of a disaster on households and agriculture (Owens et al. 2003; Skoufias 2003; Healy and Malhotra 2009). This study shows that municipalities have an interest in implementing a natural hazard prevention strategy. On the one hand, because the central government does not provide them with full insurance against natural hazards. On the other hand, because prevention can limit the damage to local government accounts. These results provide public policy perspectives on natural hazard prevention.

Nevertheless, an important question is whether the reactions are different depending on the scale and intensity of the disaster? In the context of climate change, the number of natural disasters and their intensity is likely to increase. Will municipalities be able to recover from these shocks if they occur more regularly and if the damage is more severe? Will natural hazard prevention still be able to sufficiently mitigate the effects of the shock? Future research should examine the effects of more frequent and more powerful disasters on the ability of municipalities to recover and their resilience to climate events. The question of resilience can also be asked with regard to other types of shocks such as health crises like the coronavirus, in order to understand whether municipalities are able to recover from this particular type of disaster.

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7 Appendix

7.1 Descriptive statistics

Table 7: Descriptive statistics of municipal characteristics

	minimum	median	mean	maximum
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
	% distribution			
Natural Hasard Prevention Plan	25.43 %			
Political Colour				
Unlabelled	80.55 %			
Far Left	1.42 %			
Left	11.72 %			
Ecologist	0.05 %			
Center	0.41 %			
Right	3.57 %			
Far Right	0.0 %			

Descriptive statistics of municipal characterisitics This table shows the descriptive statistics of the different demographic, socio-economic, political and environemental charasteristics. It is based on a sample of 34,627 French municipalities between 2000 and 2019. *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).

Table 8: 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

Descriptive statistics of municipal accounts This table shows the descriptive statistics of the different municipal accounts. 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).

7.2 Robustness Checks

7.2.1 Sensitivity analysis

Table 9: Sensitivity analysis of the Impact of Natural disaster on local gouvernment expenditures

	Fixed Effect - Within Estimator								
	Single disaster			No disaster History			No disaster after 2015		
	Expenditure	Revenue	Debt	Expenditure	Revenue	Debt	Expenditure	Revenue	Debt
Shock_{τ}	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)
$\text{Shock}_{\tau-1}$	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)
$\text{Shock}_{\tau-2}$	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)
$\text{Shock}_{\tau-3}$	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)
$\text{Shock}_{\tau-4}$	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)
$\text{Shock}_{\tau-5}$	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)
$\text{Shock}_{\tau-6}$	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)
$\text{Shock}_{\tau-7}$	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)
$\text{Shock}_{\tau-8}$	−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)
$\text{Shock}_{\tau-9}$	−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)
$\text{Shock}_{\tau-10}$	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
Municipalities	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 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.

Table 10: Impact of Natural disaster without control variables

	Fixed Effect - Within estimator			
	Expenditure	Revenue	Grants	Debt
Shock_{τ}	0.004*	0.003*	0.006	0.028**
	(0.002)	(0.002)	(0.020)	(0.014)
$\text{Shock}_{\tau-1}$	0.004*	0.001	0.010	0.034**
	(0.002)	(0.002)	(0.022)	(0.015)
$\text{Shock}_{\tau-2}$	0.006**	0.005**	0.042**	0.042**
	(0.002)	(0.002)	(0.021)	(0.017)
$\text{Shock}_{\tau-3}$	0.005*	0.003	0.034	0.039**
	(0.003)	(0.002)	(0.021)	(0.018)
$\text{Shock}_{\tau-4}$	0.003	0.002	0.034	0.037**
	(0.003)	(0.003)	(0.021)	(0.018)
$\text{Shock}_{\tau-5}$	0.003	0.001	0.026	0.031
	(0.003)	(0.003)	(0.024)	(0.019)
$\text{Shock}_{\tau-6}$	0.004	−0.002	0.013	0.007
	(0.003)	(0.003)	(0.022)	(0.021)
$\text{Shock}_{\tau-7}$	0.003	0.006**	0.014	0.004
	(0.003)	(0.003)	(0.027)	(0.021)
$\text{Shock}_{\tau-8}$	−0.001	0.005	0.011	−0.017
	(0.003)	(0.003)	(0.030)	(0.022)
$\text{Shock}_{\tau-9}$	0.004	0.003	0.005	−0.029
	(0.003)	(0.003)	(0.032)	(0.022)
$\text{Shock}_{\tau-10}$	0.005	0.004	0.005	−0.0004
	(0.004)	(0.003)	(0.043)	(0.022)
Observations	686,890	686,890	686,890	686,890
R^2	0.010	0.015	0.0004	0.001

Note : *p<0.1; **p<0.05; ***p<0.01 ; All models don't control for any time-variant characteristics to test the impact of control variables in the estimation, there is only time and invidividual fixed-effect. Heteroskedasticity-consistent Standard errors in parentheses, using White's covariance matrix.

Table 11: Impact of Natural disaster using raw data

	Fixed Effect - Within estimator			
	Expenditure	Revenue	Grants	Debt
Shock_{τ}	0.008^{***}	0.007^{***}	-0.001	0.032^{**}
	(0.002)	(0.002)	(0.003)	(0.013)
$\text{Shock}_{\tau-1}$	0.007^{***}	0.004^{**}	0.005	0.036^{***}
	(0.002)	(0.002)	(0.003)	(0.014)
$\text{Shock}_{\tau-2}$	0.005^{**}	0.003^{*}	0.016^{***}	0.039^{**}
	(0.002)	(0.002)	(0.003)	(0.015)
$\text{Shock}_{\tau-3}$	0.005^{**}	0.003	0.015^{***}	0.038^{**}
	(0.002)	(0.002)	(0.003)	(0.016)
$\text{Shock}_{\tau-4}$	0.003	0.001	0.013^{***}	0.033^{**}
	(0.002)	(0.002)	(0.003)	(0.016)
$\text{Shock}_{\tau-5}$	0.003	0.001	0.009^{***}	0.024
	(0.002)	(0.002)	(0.004)	(0.017)
$\text{Shock}_{\tau-6}$	0.002	-0.002	0.009^{**}	0.003
	(0.003)	(0.002)	(0.004)	(0.018)
$\text{Shock}_{\tau-7}$	0.002	0.003	0.013^{***}	0.002
	(0.003)	(0.002)	(0.004)	(0.019)
$\text{Shock}_{\tau-8}$	-0.003	0.001	0.013^{***}	-0.018
	(0.003)	(0.003)	(0.005)	(0.019)
$\text{Shock}_{\tau-9}$	0.001	-0.001	0.016^{***}	-0.027
	(0.003)	(0.003)	(0.004)	(0.019)
$\text{Shock}_{\tau-10}$	0.003	0.001	0.010^{**}	0.004
	(0.003)	(0.003)	(0.005)	(0.019)
Observations	629,525	629,525	629,525	629,525
R^2	0.186	0.238	0.083	0.012

Note : *p<0.1; **p<0.05; ***p<0.01 ; All models don't control for any time-variant characteristics to test the impact of control variables in the estimation, there is only time and invidividual fixed-effect. Heteroskedasticity-consistent Standard errors in parentheses, using White's covariance matrix.

7.2.2 Intensity analysis

Table 12: Impact of natural disasters on local government expenditures using different time-based measures of disaster occurrence

	Fixed Effect - Within estimator								
	less than one month			less than one week			less or equal to one day		
	Expenditure	Revenue	Debt	Expenditure	Revenue	Debt	Expenditure	Revenue	Debt
Shock_{τ}	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)
$\text{Shock}_{\tau-1}$	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)
$\text{Shock}_{\tau-2}$	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)
$\text{Shock}_{\tau-3}$	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)
$\text{Shock}_{\tau-4}$	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)
$\text{Shock}_{\tau-5}$	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)
$\text{Shock}_{\tau-6}$	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)
$\text{Shock}_{\tau-7}$	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)
$\text{Shock}_{\tau-8}$	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)
$\text{Shock}_{\tau-9}$	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)
$\text{Shock}_{\tau-10}$	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 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.

Table 13: Impact of Natural disaster on local gouvernment expenditures according to the type of shock

	Fixed Effect - Within estimator					
		Flood			Drought	
	Expenditure	Revenue	Debt	Expenditure	Revenue	Debt
Shock_{τ}	0.014***	0.013***	0.039**	0.001	0.001	0.014
	(0.003)	(0.002)	(0.020)	(0.005)	(0.005)	(0.032)
$\text{Shock}_{\tau-1}$	0.019***	0.013***	0.048**	−0.017***	−0.008	0.049
	(0.003)	(0.003)	(0.021)	(0.006)	(0.006)	(0.038)
$\text{Shock}_{\tau-2}$	0.011***	0.009***	0.052**	−0.014*	−0.013**	0.037
	(0.003)	(0.003)	(0.023)	(0.008)	(0.007)	(0.045)
$\text{Shock}_{\tau-3}$	0.005*	0.006**	0.037	0.0001	−0.009	0.066
	(0.003)	(0.003)	(0.024)	(0.008)	(0.007)	(0.049)
$\text{Shock}_{\tau-4}$	0.003	−0.0001	0.029	0.0001	−0.007	0.041
	(0.003)	(0.003)	(0.024)	(0.008)	(0.007)	(0.052)
$\text{Shock}_{\tau-5}$	0.010***	0.005*	0.016	−0.007	−0.007	0.083
	(0.003)	(0.003)	(0.025)	(0.008)	(0.007)	(0.051)
$\text{Shock}_{\tau-6}$	0.005	0.003	−0.013	−0.010	−0.019***	0.088*
	(0.003)	(0.003)	(0.026)	(0.008)	(0.007)	(0.053)
$\text{Shock}_{\tau-7}$	0.004	0.003	−0.010	−0.015*	−0.015**	0.084
	(0.004)	(0.003)	(0.027)	(0.008)	(0.008)	(0.052)
$\text{Shock}_{\tau-8}$	0.001	−0.001	−0.037	−0.022**	−0.012	0.054
	(0.004)	(0.003)	(0.028)	(0.009)	(0.008)	(0.055)
$\text{Shock}_{\tau-9}$	−0.001	−0.002	−0.052*	−0.012	−0.013	0.093*
	(0.004)	(0.004)	(0.028)	(0.010)	(0.008)	(0.055)
$\text{Shock}_{\tau-10}$	0.002	0.002	−0.018	−0.012	−0.025***	0.110**
	(0.004)	(0.004)	(0.028)	(0.009)	(0.009)	(0.052)
Observations	415,810	415,810	415,810	261,272	261,272	261,272
Municipalities	23,232	23,232	23,232	14,902	14,902	14,902
R^2	0.185	0.233	0.010	0.170	0.222	0.009

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.

7.2.3 Placebo test and common trend hypothesis

Table 14: Placebo test of the impact of Natural disaster on municipal expenditures

	Fixed Effect - Within estimator			
	Expenditure	Revenue	Operating grant	Debt
$\text{Shock}_{\tau+2}$	−0.0001	0.002	−0.006	0.025
	(0.002)	(0.002)	(0.004)	(0.016)
$\text{Shock}_{\tau+1}$	0.001	0.004	−0.007	0.023
	(0.002)	(0.002)	(0.004)	(0.017)
Shock_{τ}	0.003*	0.007***	−0.010*	0.039*
	(0.001)	(0.002)	(0.005)	(0.016)
$\text{Shock}_{\tau-1}$	0.004**	0.005**	−0.015**	0.045**
	(0.001)	(0.002)	(0.005)	(0.017)
$\text{Shock}_{\tau-2}$	0.003*	0.004*	−0.003	0.047**
	(0.002)	(0.002)	(0.005)	(0.018)
$\text{Shock}_{\tau-3}$	0.003*	0.004	−0.002	0.044*
	(0.002)	(0.002)	(0.005)	(0.019)
$\text{Shock}_{\tau-4}$	0.005**	0.002	0.001	0.040*
	(0.002)	(0.002)	(0.005)	(0.019)
$\text{Shock}_{\tau-5}$	0.005**	0.001	0.010*	0.030
	(0.002)	(0.002)	(0.005)	(0.020)
$\text{Shock}_{\tau-6}$	0.004*	−0.001	0.008	0.008
	(0.002)	(0.002)	(0.006)	(0.021)
$\text{Shock}_{\tau-7}$	0.004*	0.004	0.011	0.008
	(0.002)	(0.003)	(0.006)	(0.022)
$\text{Shock}_{\tau-8}$	0.004*	0.002	0.022**	−0.015
	(0.002)	(0.003)	(0.007)	(0.022)
$\text{Shock}_{\tau-9}$	0.004*	−0.0003	0.018*	−0.023
	(0.002)	(0.003)	(0.007)	(0.022)
$\text{Shock}_{\tau-10}$	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 ; 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.