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Natural Hazards and Local Public Policies

Carla Morvan

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Carla MORVAN

Natural Hazards and Local Public Policies.

Devant le jury composé de :

Lionel RAGOT, Professeur, Université Paris Nanterre, Président

Jérôme HÉRICOURT, Professeur, Université Paris-Saclay, Rapporteur

Raphaël SOUBEYRAN, Directeur de recherche, INRAE, Rapporteur

Sophie LEGRAS, Chargée de recherche, INRAE, Examinatrice

Sonia PATY, Professeure, Université Lumière Lyon 2, Directrice de thèse

Frédéric JOUNEAU, Professeur, Université Lumière Lyon 2, Co-Directeur de thèse

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THESE DE DOCTORAT EN SCIENCES ECONOMIQUES

Présentée en vue de l'obtention du grade de docteur de l'Université de Lyon,
délivré par l'Université Lumière Lyon 2

Natural Hazards and Local Public Policies

Soutenue par

Carla MORVAN

Dirigée par :

Sonia Paty Professeure des Universités, Université Lumière Lyon 2
Frédéric Jouneau Professeur des Universités, Université Lumière Lyon 2

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Devant le jury composé de :

Lionel Ragot	Professeur, Université Paris Nanterre	(Président)
Jérôme Héricourt	Professeur, Université Evry-Paris-Saclay	(Rapporteur)
Raphaël Soubeyran	Directeur de recherche, INRAE	(Rapporteur)
Sophie Legras	Chargée de recherche, INRAE	(Examinatrice)

Université de Lyon - Ecole doctorale de Sciences Economiques et de Gestion

Université Lumière Lyon 2

Groupe d'Analyse et de Théorie Economique, Lyon Saint Etienne

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Contents

Résumé de la thèse	1
Introduction	5
1 Municipalities' budgetary responses to natural disasters	19
1.1 Introduction	20
1.2 Institutional context	22
1.2.1 The particular features of natural disasters	22
1.2.2 Administrative organization: governments' roles and grants	24
1.3 Data	25
1.4 Methodology	26
1.4.1 Difference in Difference approaches	26
1.4.2 Panel Vector Autoregression Model	30
1.5 Results	31
1.5.1 Impact of natural disasters on the main municipal budget ac- counts	31
1.5.2 Impact of natural disasters on the sub-accounts	35
1.5.3 Financial health: A key factor in recovery	38
1.5.4 Robustness Checks	40
1.6 Discussion and conclusion	42
References	45
A Appendix	48
A.1 Descriptive statistics	48
A.2 Additionnal results	49
A.3 Robustness Checks	53
2 Optimal Management of Local Budget subject to Capital Shocks	59
2.1 Introduction	60
2.2 The model	62
2.2.1 Municipal Planner's Problem	63
2.2.2 Municipality constrained by debt	67
2.3 Data	69

2.4	Calibration	72
2.5	Simulation	75
2.6	Conclusion	79
	References	81
B	Appendix	83
	B.1 Solution validity	83
	B.2 Creation of constrained and unconstrained groups from data	83
3	Natural disasters and voter gratitude: What is the role of prevention policies?	85
3.1	Introduction	86
3.2	Institutional context	88
	3.2.1 Municipal elections in France	88
	3.2.2 Natural disasters	89
	3.2.3 Natural hazard prevention policies	89
3.3	Data	91
3.4	Methodology	93
	3.4.1 The causal impact of natural disasters on municipal budgets	93
	3.4.2 The causal impact of natural disasters on electoral outcomes	94
3.5	Effect of natural disaster on budget outcomes according to implementation of a prevention plan	95
3.6	Evidence on the impact of natural disasters on electoral outcomes	100
3.7	Conclusion	103
	References	105
C	Appendix	107
	C.1 Descriptive statistics	107
	C.2 Additional results: Effect on municipal accounts	108
	C.3 Additional results: Electoral outcomes	114
	Conclusion	121

List of Figures

1.1	Share of natural disaster by type since 1982	22
1.2	Natural disasters in France since 1982	23
1.2a	Floods	23
1.2b	Storms	23
1.2c	Land mvmt	23
1.2d	Droughts	23
1.3	Effect of a natural disaster on the main budget accounts	33
1.3a	Expenditures	33
1.3b	Revenues	33
1.3c	Grants	33
1.3d	Debt	33
1.4	Dynamic response of main accounts to natural disaster	35
1.5	Effect of a natural disaster on the expenditure sub-accounts	36
1.5a	Salary expenses	36
1.5b	Purchases	36
1.5c	Capital expenditures	36
1.5d	Loan repayment	36
1.6	Effect of a natural disaster on the revenue sub-accounts	37
1.6a	Local tax revenues	37
1.6b	Operating grants	37
1.6c	Investment grants	37
1.6d	Loans	37
1.7	Dynamic response of main accounts to natural disaster: by financial health groups	39
1.7a	Group 1: “Very good”	39
1.7b	Group 3: “Average or poor”	39
A.8	Dynamic response of main accounts to natural disaster by financial health groups: Group 2: “Good”	52
A.9	Impact of natural disaster on local government expenditures: Common Trend	54
A.10	Impact of natural disaster by type of shocks: Flood	54

List of Figures

A.11	Impact of natural disaster by type of shocks: Drought	54
A.12	Effect of a major natural disaster on the main budget accounts . . .	57
A.12a	Expenditures	57
A.12b	Revenues	57
A.12c	Grants	57
A.12d	Debt	57
2.3.1	AFL ranking by group (Financial Health Indicator)	72
2.5.1	Simulation unconstrained case	76
2.5.1a	Capital	76
2.5.1b	Investment	76
2.5.1c	Debt	76
2.5.2	Simulation constrained case	77
2.5.2a	Capital	77
2.5.2b	Investment	77
2.5.2c	Current Expenditures	77
2.5.2d	Taxes	77
2.5.3	Simulation of current welfare (V_t)	78
3.2.1	Distribution of natural disasters and prevention plans since 1982 . .	90
3.5.1	Effect of a natural disaster on budget accounts according to imple- mentation of a prevention plan	96
3.5.1a	Expenditures	96
3.5.1b	Revenues	96
3.5.1c	Grants	96
C.1	Common trend before shock - general case without NHPP	112
C.2	Common trend before shock - general case with NHPP	112
C.3	Impact of natural disasters on local government accounts according to their adherence to a NHPP: major natural disaster	113
C.3a	Expenditures	113
C.3b	Revenues	113
C.3c	Grants	113

List of Tables

1.1	Impact of natural disasters on main municipal accounts	32
A.2	Descriptive statistics of municipal accounts	48
A.3	Dynamic impact of natural disaster on local governments main ac- counts	49
A.4	Impact of natural disaster on local government expenditures - sub- accounts	50
A.5	Impact of natural disaster on local government revenues - sub-accounts	51
A.6	Descriptive statistics of different level groups	52
A.7	Impact of natural disaster on local government expenditures: Placebo Test	53
A.8	Sensitivity analysis of the impact of natural disasters on local govern- ment expenditures	55
A.9	Impact of natural disasters on local government expenditures using different disaster frequency measures	56
2.3.1	Descriptive statistics of municipal accounts	70
2.4.1	Parameters calibration and estimation	73
B.1	Descriptive statistics for constrained and unconstrained groups, ag- gregated at the municipal level	84
3.5.1	Triple difference estimation results	98
3.6.1	Heckman Model - Occurrence of natural disaster during the electoral cycle	102
C.1	Descriptive statistics	107
C.2	Impact of natural disasters on local government accounts according to their adherence to a NHPP: TWFE	108
C.3	Impact of natural disasters on local government accounts according to their adherence to a NHPP: Placebo test	109
C.4	Impact of natural disasters on local government accounts according to their adherence to a NHPP: Xynthia Storm	110
C.5	Regression Results according to type of shocks	111

List of Tables

C.6	Heckman Model - Occurrence of natural disaster at different times in the cycle	114
C.7	Heckman Model - Occurrence of a major natural disaster during the election cycle	115
C.8	Heckman Model - Occurrence of natural disaster during the electoral cycle: Types of shock	116
C.9	Heckman Model - Political variables - Sample with proportional, list, two-round voting system	117
C.10	Probit Model - Occurrence of natural disaster during the electoral cycle - all candidates, regardless of competition - Sample with majority, multi-member, two-round system	118
C.11	Heckman Model - Occurrence of natural disaster during the electoral cycle: control variables	119
C.12	Heckman Model - Occurrence of natural disaster during the electoral cycle: full table	120

Résumé de la thèse

Les catastrophes naturelles sont des événements dramatiques qui touchent tous les territoires et peuvent avoir pour conséquence la destruction ou la mort. D'après les différents rapports du GIEC (Groupe d'experts intergouvernemental sur l'évolution du climat), le changement climatique va entraîner une augmentation du nombre, de la durée et de l'intensité des catastrophes naturelles (Field et al. 2012). Depuis l'an 2000, le nombre d'inondations majeures dans le monde a plus que doublé, constituant ainsi le risque le plus important (UNDRR 2020). En France, 17 millions de personnes sont exposées au risque d'inondation. En moyenne chaque année, 5700 communes sont touchées par une catastrophe naturelle, et cette moyenne risque d'augmenter avec le dérèglement climatique (Antoni & Joassard 2023).

Les gouvernements locaux sont affectés par les catastrophes naturelles. Les municipalités elles-mêmes peuvent être considérées comme des victimes. En effet, les biens publics locaux, tels que les routes, les ponts, les digues ou les voies ferrées, sont également détruits et endommagés lors d'une tempête. De plus, les municipalités sont le niveau de gouvernement le plus proche des citoyens et donc le mieux placé pour répondre en cas de crise. C'est d'ailleurs le maire qui est responsable de la sécurité de ses administrés pendant une catastrophe. Après la crise, la commune est également responsable de la continuité du service public, ce qui inclut la réparation et la reconstruction. Enfin, la municipalité est également chargée de la prévention des catastrophes naturelles. Le maire peut donc être tenu responsable en cas de manquement ou d'erreur, que ce soit dans la gestion avant ou pendant la catastrophe.

Les municipalités sont au cœur des enjeux des catastrophes naturelles, à la fois parce qu'elles peuvent être victimes des dommages causés, entraînant ainsi des coûts directs, et parce qu'elles sont tenues pour responsables. Cela peut entraîner des coûts indirects, notamment pour l' élu qui doit assumer ses décisions devant ses électeurs et parfois même devant la loi.

Cette thèse a pour objectif d'éclairer la question de l'influence des catastrophes naturelles sur les choix de politique publique locale. A la fois les choix budgétaires, les décisions en terme de prévention des risques et leurs conséquences électorales

Les deux premiers chapitres se concentrent sur les coûts directs, c'est-à-dire les réactions budgétaires des municipalités suite à une catastrophe naturelle. L'objectif étant, tout d'abord dans le Chapitre 1, d'observer empiriquement les effets d'une catastrophe naturelle sur divers agrégats budgétaires des municipalités françaises. Dans le deuxième chapitre, le même objectif est abordé d'un point de vue théorique pour comprendre les relations dynamiques entre les comptes.

Enfin, le troisième chapitre se concentre sur la prévention des risques naturels. Dans un premier temps, il évalue l'efficacité des plans de prévention pour atténuer les effets d'une catastrophe, ensuite, il vise à observer les répercussions sur les élus aux élections municipales.

Le premier chapitre examine l'impact des catastrophes naturelles sur les budgets des municipalités en France. Pour ce faire, j'utilise deux méthodologies dynamiques afin d'estimer comment les gouvernements locaux réagissent aux événements catastrophiques majeurs. La première méthode est une approche de différences en différences à plusieurs périodes. Cette méthode permet d'identifier l'impact causal des catastrophes naturelles sur le budget d'une municipalité, en tenant compte de l'occurrence sporadique de ces événements. Cependant, bien que cette méthodologie prenne en compte l'effet échelonné du traitement, elle analyse les comptes individuellement et peut négliger l'endogénéité entre les comptes municipaux. Pour résoudre ce problème, j'utilise un modèle de panel à vecteurs autorégressifs, inspiré par la littérature macroéconomique sur les chocs naturels. Cette méthode prend en compte l'endogénéité des principaux comptes municipaux à l'aide d'un vecteur de variables de résultat.

Je constate que les dépenses, les recettes et les subventions municipales augmentent de manière significative immédiatement après une catastrophe naturelle, cet effet semble persister pendant 2 à 6 ans après le choc. Dans un second temps, je mène une analyse sur les "sous-comptes" municipaux pour comprendre la nature des dépenses ou des recettes impliquées. Je constate que le compte des dépenses d'équipement est affecté, augmentant après la catastrophe, ainsi que celui des dépenses salariales et des achats courants qui augmentent également. Du côté des recettes, on observe une augmentation des subventions d'investissement dans les deux années suivant les catastrophes, puis des subventions de fonctionnement après 6 ans. On remarque enfin, une augmentation des recettes fiscales après 5 ans, ce qui indique que le gouvernement central ne fournit pas une compensation complète pour les dommages causés par les catastrophes, amenant les municipalités à augmenter les impôts.

Enfin, j'utilise un indicateur de santé financière municipale pour classer les municipalités en trois groupes : (i) très bonne, (ii) bonne, et (iii) moyenne ou mauvaise

santé financière. Je constate que les catastrophes naturelles semblent n'avoir aucun effet significatif sur les municipalités ayant une très bonne santé financière. Cependant, à mesure que la santé financière diminue, les effets du choc deviennent plus prononcés. Cette analyse soulève des questions sur l'hétérogénéité financière des municipalités et le rôle de la santé financière dans leur gestion des risques, que j'explorerai davantage dans le deuxième chapitre.

Le deuxième chapitre cherche à comprendre les liens dynamiques entre les comptes budgétaires locaux après une catastrophe naturelle. Nous construisons et calibrons un modèle représentant une municipalité qui pourrait être affectée par une catastrophe naturelle, entraînant la destruction d'une partie de son stock de capital. La municipalité, agissant en tant que décideur bienveillant, cherche à maximiser le bien-être de ses citoyens en fonction de la quantité de biens et de services publics. La production de biens publics utilise le stock de capital, qui augmente grâce à l'investissement, et le niveau de dépenses courantes. Le financement des dépenses courantes, des investissements et des dépenses financières est réalisé par le biais des impôts, des subventions et éventuellement de l'accumulation de dettes.

Dans ce cadre général, nous analysons deux types de situations : les municipalités ayant la capacité d'endettement et celles contraintes sur l'endettement. Dans le premier scénario, la réduction du stock de capital est instantanément compensée par une augmentation de l'investissement financé par la dette. Dans le deuxième scénario, où la santé financière de la municipalité ne permet pas l'endettement, l'augmentation de l'investissement pour contrer la catastrophe naturelle est financée par les impôts et une réduction des dépenses courantes.

Le dernier chapitre examine les politiques de prévention contre les catastrophes naturelles. Cette troisième partie analyse, d'une part, l'efficacité des politiques de prévention pour limiter l'impact des catastrophes naturelles sur les budgets municipaux. D'autre part, elle estime l'influence de la survenue des catastrophes naturelles et de la mise en œuvre des politiques de prévention sur les résultats électoraux municipaux. En utilisant une méthodologie de différences en différences échelonnées et une approche de triple différence, nous constatons que l'effet des catastrophes naturelles sur les budgets municipaux est significativement atténué lorsque des politiques de prévention des risques naturels sont mises en œuvre au niveau municipal. En revanche, les municipalités sans plan de prévention préexistant avant un choc subissent des effets importants sur leurs comptes budgétaires.

Nous observons que, bien que les politiques de prévention puissent atténuer efficacement les dommages causés par les chocs naturels, la mise en œuvre de telles politiques a un effet négatif sur la probabilité de réélection d'un maire. Pour anal-

yser l'effet des catastrophes naturelles et des politiques de prévention sur les probabilités de réélection, nous utilisons un modèle de Heckman afin de considérer le biais de sélection résultant des décisions individuelles des maires de se représenter aux élections. Nos résultats indiquent que (i) la survenue de catastrophes naturelles affecte négativement les probabilités de réélection, et (ii) les citoyens désapprouvent les plans de prévention. Cela soutient la notion de “myopie des électeurs” : les électeurs peuvent ne pas percevoir les effets à court et à long terme des politiques de prévention sur les budgets locaux, les incitant à punir les décideurs pour la mise en œuvre de ces politiques.

Cette thèse met en lumière plusieurs résultats importants qui contribuent à la littérature en économie publique locale. Tout d'abord, je démontre, dans le cas français, que les catastrophes naturelles ont des effets négatifs sur les budgets des communes et que ces effets peuvent perdurer plusieurs années après la catastrophe. De plus, je montre que les politiques de prévention contre les risques naturels peuvent considérablement atténuer ces impacts négatifs. Ces politiques publiques à l'échelle communale sont efficaces pour limiter les effets budgétaires sur les communes. Enfin, j'observe que les citoyens ont une perception négative des catastrophes naturelles et des mesures de prévention, et semblent les attribuer à leurs élus locaux. Ainsi, les maires voient leurs chances de réélection diminuer s'ils ont été confrontés à une catastrophe naturelle ou s'ils ont mis en œuvre des mesures préventives, même si ces dernières se sont avérées efficaces.

Introduction

A natural disaster is an unexpected event that dramatically upends the normal course of events, frequently causing destruction or fatalities. According to various reports from the IPCC (Intergovernmental Panel on Climate Change), climate change brings about changes in the frequency, duration, and intensity of climate events, including natural disasters (Field et al. 2012). Since 2000 in the world, the number of major floods has more than doubled, while the incidence of storms grew by 40%. Floods and storms were the most prevalent events. There were 7,348 major recorded disasters claiming 1.23 million lives, affecting 4.2 billion people and resulting in approximately US\$2.97 trillion in global economic losses (UNDRR 2020). In France, 17 million individuals are exposed to a risk of flooding, the most frequent risk in hexagonal France. On average, 5700 municipalities are affected by a natural disaster each year, representing approximately 15% of the territory. This average is likely to increase in light of climate change (Antoni & Joassard 2023). However, citizens seem to have little aware of these environmental risks. On the other hand, they emphasize the role of public authorities and local governments in information and prevention of natural hazards (Pautard 2023).

Natural disasters are mainly local issues. While states have a role in global crisis management, it is the local stakeholders who are affected by these crises. It is rare for a natural disaster to cause difficulties at the national or supranational government level. The consequences of these major events are often at a very localized geographic level. However, research on the economic aftermath of natural disasters has predominantly focused on national or even continental scales, overlooking the local impacts. This thesis aims to provide a more detailed and precise understanding of the budgetary and political consequences of natural disasters on local governments.

The most dramatic consequence caused by a natural disaster is obviously the loss of lives and missing persons. Over the last century, France has recorded more than 32,000 deaths attributable to a natural disaster, in addition to the three largest heatwaves of the last 20 years, which alone claimed 18,000 lives. Floods account for 3% of deaths, compared to 6% for storms and 1% for earthquakes. The deadliest

disasters are volcanic eruptions, but the disasters causing deaths most frequently are floods, i.e., 67% of deadly events. The deadliest flood in the last 40 years occurred after the Xynthia storm in 2010, where 53 people died and more than 200 people were injured as a result of the storm (Antoni & Joassard 2023).

Human casualties are not the only consequences of natural disasters. There are also significant material and psychological damages for the victims. Taking the example of the floods in northern France and Italy in October and November 2023, where several storms occurred¹. This was an uncommon and large-scale climatic event, and although there were no deaths recorded, numerous damages are to be noted. Firstly, 262 municipalities were affected, with 5,849 homes being flooded. Additionally, 98 shops and 95 businesses were directly affected. It's noteworthy that several households faced water restrictions and were deprived of electricity for several days (Faranda, Yiou, et al. 2023). The state services in Pas-de-Calais also highlight that the floods could have a significant psychological impact on the victims. These state services also offer support to all local stakeholders, individuals, businesses, farmers, and local authorities. Public amenities are also to be considered as they can be affected by natural disasters, including roads, dikes, or damaged railways, electricity or water networks, and communal forests.

The damages caused by natural disasters incur numerous costs. Over the period 1982-2022, insurers paid out €49.9 billion under the natural disaster insurance. The most costly disasters for insurers are floods and droughts, representing respectively 50% and 42% of the total costs (Antoni & Joassard 2023). For instance, the floods related to the Xynthia storm had a total cost of €2.5 billion. However, droughts seem to be the most concerning for the future, given the significant costs they generate for insurers (Le Bars 2023).

In addition to human lives and monetary losses for insurers, the economic sectors, especially real estate and agriculture, suffer from natural disasters. These losses average €4.8 billion per year, with 62% attributed to the real estate sector. Drawing on climate change scenarios developed by the IPCC, CCR (Caisse Centrale de Réassurance) studies highlight that the costs associated with natural disasters will significantly increase by 2050.

The purpose of this thesis is to understand the implications of natural disasters on local governments. So far, the effects of climate change and natural events have been viewed through the lens of individuals, businesses, or insurance companies. However, local authorities are also affected by these disasters and can be considered as victims. Indeed, the assets of local authorities can also be affected by natural disasters. There are numerous cases where town halls or schools have found them-

¹Babet, Aline, Ciaran, Domingos, Elisa, and Frederico storms

selves submerged. One can also think of the damage caused by the Xynthia storm in the Vendée municipalities in 2010, where dikes, roads, port facilities, and even electricity networks were damaged or destroyed.

In decentralized countries, there are several levels of government, and each level has specific competencies. In France, municipalities are responsible for local roads, schools, sports and cultural facilities, parks and gardens, maintenance of sewage systems, and waste treatment. 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. Regions are responsible for national parks, river ports, airfields, high schools, and they also finance infrastructure such as 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; for example, the renovation of a museum will be the responsibility of the county, while that of a school will be the responsibility of the municipality.

Some public assets can be insured such as real estate, for example. However, certain assets cannot be insured, such as roads and ancillary assets necessary for traffic safety, works of art, water distribution and sanitation networks, dikes, etc. (Maurey 2019). The repair of damages caused to these uninsured assets thus relies solely on local governments, which can represent significant costs.

In addition to the potential damages that local authorities may incur, public authorities are responsible in the event of a natural disaster. This implies that natural disasters may influence policy decisions.

Specifically, the management of a disaster is an assignment of the mayor of the affected municipality. The mayor is responsible for the safety of the residents, the implementation of rescue operations, emergency services, and also the prevention of natural disasters. In France, in the event of an accident caused by a natural risk, the mayor assumes the role of director of emergency operations². The mayor is the representative of municipal authority and police³, he is responsible for taking the first measures to protect the population and property. It is his responsibility to decide on strategic orientations and validate decisions during the crisis in his municipality, as long as the event does not exceed municipal limits. One of the mayor's responsibilities is also to inform, alert, and evacuate the population⁴.

After the crisis, it is the mayor's responsibility to ensure the continuity of public

²Article L.742-1 of the Code de Sécurité Intérieur

³Article L.2212-2 of the Code Général des Collectivités Territoriales

⁴Articles L.2212-1 and following of the Code Général des Collectivités Territoriales and articles L.511-1 and following of the Code de Sécurité Intérieur

services. The municipality must find solutions and enable its citizens to benefit from essential public services under the responsibility of the municipality. The municipality is also responsible for the restoration of its assets, whether insured or not, although it can seek and benefit from the assistance of other levels of government.

Another responsibility falls on the mayor, that of the prevention of natural risks⁵. In this regard, the municipality has various tools, including the ability to prescribe or carry out protective works. The main public policy at the municipal level for the prevention of natural risks is the “Plan de prévention des risques naturels” (i.e. “Natural Hazard Prevention Plan”, NHPP). It is often multi-risk, meaning that it focuses on several types of risks in the territory, but it can also be for a single risk, such as floods or drought.

The NHPP is a policy centralized by the prefect of the county but implemented at the municipal level. We witness here a complex intertwining of different levels of local government. The prefect is therefore responsible for the elaboration of the NHPP on behalf of the State until the plan is approved. However, it is the mayor of the municipality who is responsible for the prevention of accidents under the law⁶. The creation of a NHPP may have two sources: (i) the plan can be prescribed by the prefect when a risk is perceived. Conversely, (ii) the mayor, in adherence to his legal obligations, may request the creation of the plan. The main role of this type of plan is to delimit the areas that are subject to a risk of natural disaster. Either the directly exposed areas, where construction and exploitation are prohibited, or less exposed areas where exploitation is regulated⁷. The plan can also prescribe works necessary for the prevention of risks.

The municipality and the mayor have significant responsibilities in the event of a natural disaster. This local government, closest to the citizens and at the core of crises, is thus responsible for the prevention of natural disasters, their management during the crisis, and the continuity of public services afterward.

Beyond being responsible, it is also the municipality that is held accountable in case of failure or error during a dramatic event. Bulteau (2013) highlights that decentralization, the increasing competencies of local governments, the desire to moralize public life, and the penalization of accidents have paved the way for the diffusion of criminal risk in local governments. The most striking example is the trial of the former mayor of La Faute-sur-Mer, who was sentenced to 4 years in prison

⁵Article L.2212-2-5° of the Code Général des Collectivités Territoriales places on the mayor, holder of municipal police powers, a general obligation to prevent natural accidents and disasters of all kinds.

⁶Article L.2212-2-5° of the Code Général des Collectivités Territoriales

⁷Article L. 562-1 of the Environmental Code

and fined €30,000 for involuntary manslaughter and endangerment of others, before filing an appeal⁸. This conviction arises because mayors can be held accountable for offenses such as intentionally endangering others, acting recklessly, displaying negligence, or failing to meet legal obligations regarding caution and safety⁹.

However, citizens' perception of local government responsibility in the face of risks is less clear. A survey conducted by the Ministry of the Environment reveals that, 51% of respondents believe that risk protection is an individual responsibility, while 49% think it is the responsibility of public authorities. Moreover, 47% of citizens do not trust the public policies implemented in the face of risks (Pautard 2023).

Local elected officials can thus be held accountable in the event of a natural disaster, both from a legal perspective and by their constituents, who may be skeptical of their management and implemented policies. These challenges can have political consequences for elected officials, especially regarding their potential re-election.

The issue of natural disasters at the local level is complex, involving the challenges posed by the disasters themselves, which represent a growing risk, as well as the issue of the costs these disasters incur for local governments and the resulting policy implications.

The economic literature on this matter initially focused on the effects of natural disasters on individuals and businesses, addressing issues such as poverty, living conditions, and the impact on industries and agriculture (see Kousky 2014).

It also delved into the effects of shocks on the budgetary behaviors of central governments at the macroeconomic level. From a theoretical standpoint, the optimal response of a government to a shock is to smooth its fiscal and budgetary fluctuations over time (Barro 1979 ; Lucas & Stokey 1987). However, the specificity of natural disasters has only been empirically explored (Noy & Nualsri 2011 ; Melecky & Raddatz 2011).

While focusing on the local level allows for a closer examination of the impacts of natural disasters, it also enables comparisons that are not feasible at the national or supranational level. This is because natural disasters often affect specific areas intensely, and their effects can vary significantly across different regions.

The aim of this thesis is to concentrate on the consequences of natural disasters at the local level and understand how they influence the budgetary and policy decisions of municipalities.

⁸Indeed, 29 people lost their lives during the Xynthia storm in this municipality.

⁹Article 121-3 of the Penal Code

The literature in local public economics has revealed the effects of natural disasters on the budgets of local authorities. These studies show that local governments tend to increase their expenditures and revenues following a natural disaster, including Jerch et al. (2023) in the South USA, Masiero & Santarossa (2020) in Italy, Miao, C. Chen, et al. (2020) in China, Panwar & Sen (2020) in India, and Miao, Hou, et al. (2018) in US States. However, these studies do not agree on the direction of long-term effects, likely due to the different institutional contexts of the regions studied. Some show that local governments will increase their expenses in the long term (e.g., Masiero & Santarossa 2020), while others show a decrease in the provision of local public goods (Jerch et al. 2023).

On the other hand, this literature also explores the relationships between different levels of government following a shock, particularly the subsidies offered by higher-level governments. A “flypaper effect” is observed, meaning that post-disaster grants stimulate the expenditures of local governments.

These intergovernmental relationships also reveal questionable effects in terms of public policy (Wildasin 2008). Notably, a potential solution that may emerge is that a local government has no interest in funding a natural disaster prevention strategy since higher-level governments provide insurance in the form of subsidies following the shock. 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 & Haughwout 2012 ; Lohse & Robledo 2013 ; Turati & Buzzacchi 2014).

Another way to encourage public authorities to invest in risk protection could be the electoral mechanism. However, this question has been relatively underexplored in the literature, except for Healy & Malhotra (2009), who show that voters do not reward their elected officials for investing in prevention policies. However, they also demonstrate that voters reward officials for post-disaster spending.

This second result appears in the literature under the term “retrospective voting,” meaning that voters take into account the efforts and actions implemented by their officials during a shock (Masiero & Santarossa 2021). Some even highlight that officials use this mechanism for clientelism (Klomp 2020 ; Gallego 2018 ; J. Chen 2013 ; Bechtel & Hainmueller 2011). On the other hand, voters may exhibit an opposite behavior in the event of a natural disaster. This is referred to as “blind retrospection,” meaning that voters do not consider the actions taken by their officials and may blame them for having suffered damages (Achen & Bartels 2012 ; Bovan et al. 2018).

This thesis contributes to several economic literatures, including empirical investigations in local public finance, micro-founded theoretical frameworks, and analyses

within political economy.

One of the contributions of this thesis to the literature is its insight into the French case. Indeed, the French case is unique regarding natural disasters as it is a status regulated by the state. In France, “natural disaster” is a specific status governed by the law of July 13, 1982. A climatic event can receive the status of a natural disaster following a request from the mayor of the concerned municipality and a decision from an inter-ministerial commission.

The primary objective of this status is insurance-related. It establishes a legal framework within which all citizens are insured against major catastrophic events. In France, all policyholders contribute to the “Natural Disaster” coverage by subscribing to an insurance policy (home, auto, professional, etc.). This coverage then allows compensating citizens for “direct non-insurable material damages caused by the abnormal intensity of a natural agent, when the usual measures to prevent these damages could not prevent their occurrence or could not be taken”¹⁰.

Beyond these insurance considerations, the “natural disaster” status allows identifying major climatic events whose intensity is sufficiently exceptional to qualify for this designation. Indeed, after the mayor’s request to benefit from this status, the application is supplemented by expert reports documenting the intensity and damage of the natural phenomenon. This report is then analyzed by an inter-ministerial commission, chaired by the Minister of the Interior, whose opinions determine the recognition or non-recognition of a state of natural disaster.

However, the transparency and efficiency of this commission have been criticized, leading to the establishment of a new law in December 2021¹¹. The main changes include the inclusion in the law of the role of the interministerial commission that makes annual assessments and statements on the reference systems used to assess the abnormal intensity of natural phenomena. In addition, a national consultative commission on natural disasters is created with the objective of re-evaluating the criteria of natural disasters, along with a group of experts to assist municipalities in administrative steps. Finally, the time limit for declaring damage is extended to 2 years, and the time limit for reimbursing victims is shortened¹².

The “natural disaster” system is particularly interesting for this thesis, as it has allowed for the compilation of major catastrophic events that have occurred on French territory since 1982. This database allows us to identify the territories af-

¹⁰Article L125-1 of the code des assurances

¹¹Law n° 2021-1837 of December 28, 2021

¹²In accordance with Article 3 of Ordinance n° 2023-78 of February 8, 2023, these provisions come into effect on a date set by decree and no later than January 1, 2024. As the implementation of this law has been delayed, no natural disaster status has been established according to these new provisions.

ected by disasters from those that have not been affected. The GASPAR database compiles all natural disasters at the municipal level, providing information on the event's start and end dates, as well as the type of catastrophe. Since 1982, an average of 5,700 municipalities annually received the status of natural disaster. Between 1982 and 2023 on average, authorities officially granted the "Natural Disaster" status seven times per municipality. I utilize the French context and its specificities to assess the effects of natural disasters on local governments, with a particular focus on the political and budgetary choices of municipalities.

This particular context at the local level is an interesting case study to be analyzed with several econometric methodologies. Firstly, the occurrence of a natural disaster can be considered as an exogenous event, capable of revealing individuals' reactions following a shock. This leads to event study methods as in Chapter 1. This initial microeconometrics approach presents advantages and disadvantages that are the subject of methodological debate. The main difficulty of these empirical approaches is that it is challenging to study the short-term dynamics. Therefore, I propose methodologies closer to macroeconomics, first from an empirical exploratory perspective, then from a theoretical standpoint in Chapter 2. The theoretical perspective adopted thereafter aims to study the joint dynamics of the budgetary consequences of natural disasters. This approach has the advantage of gradually understanding the dynamic path of the consequences of a shock on the accounts and between accounts. However, it requires strong assumptions. In contrast to what is done empirically, to the best of my knowledge, this is a first attempt regarding the study of local economic policies.

This thesis is divided into 3 chapters, each addressing a portion of the overarching question: How do natural disasters influence municipalities budgetary and policy decisions?

The first two chapters focus on the budgetary consequences of natural disasters on local governments. Chapter 1 empirically analyzes the budgetary responses of French municipalities to natural disasters, while Chapter 2 provides a theoretical insight into the dynamics of local government accounts following a capital shock.

Chapter 3 offers an analysis of natural hazard prevention policies (NHPP) to identify if these policies help mitigate the effects of natural disasters at the local level. Lastly, it explores the electoral consequences of natural disasters and prevention policies at the municipal level.

Chapter 1 focuses on the effects of natural disasters on the budgets of French municipalities. This chapter contributes to the empirical literature on this subject

by shedding light on the French context and understanding the effects on a variety of disaggregated municipal accounts.

Indeed, the French context is unique as France is a decentralized country with municipalities being the smallest unit. This level is particularly granular in the French context, with over 35,000 communes in the territory, with an average area of 14.9 km². The objective of this chapter is to assess the effects of natural disasters on the accounts of French municipalities between 2000 and 2019.

Firstly, the analysis focuses on the main accounts, namely total expenditure, total revenue, subsidies received, and debt. Then, the data allows disaggregating these accounts to understand more precisely what types of expenses are incurred following a disaster: expenses for new investments, for current purchases, or wage expenses; and which financing mechanisms are used to offset the shock: tax revenues, borrowing or, other subsidies.

Two dynamic methodologies are used, first a multiple period difference-in-differences approach, based on the method by Callaway & Sant'Anna (2021). This method, with a specific event study aggregation scheme, enables the identification of the causal impact of natural disasters on a municipality's budget, taking into consideration the sporadic occurrence of these events. However, while this methodology accounts for the staggered effect of the treatment, it analyzes accounts individually and may overlook the endogeneity between municipal accounts. To address this issue, I use a Panel Vector Autoregressive model, inspired by the macroeconomics literature on natural shocks. This method considers the endogeneity of the main municipal accounts using a vector of outcome variables.

These different methods lead us to believe that the expenditures, revenues, and subsidies of municipalities increase following a natural disaster, and that this effect persists for 2 to 6 years after the shock. On the revenue side, we observe an increase in investment subsidies in the 2 years following the disaster, followed by an increase in current subsidies. We also observe an increase in tax revenues after 5 years, which seems to indicate that the central government does not provide full compensation for the damages.

However, this chapter prompts us to reflect on the fact that the objective of this event study is to initiate a first analysis of these behaviors, but it does not allow us to obtain a fine identification of the effects and mechanisms. To delve deeper into this question, a theoretical model guiding us on the mechanisms of post-disaster spending would allow us to both better understand these exploratory results and also to precisely model the effects of a shock on the accounts of local authorities. This is the focus of Chapter 2.

In line with the first chapter, Chapter 2 seeks to understand the effects of a

natural disaster shock on local government budgets. However, the approach in this second chapter is different. The objective of this chapter is to model the budgetary behavior of a local planner, using a theoretical micro-founded approach.

The municipality, acting as a benevolent decision-maker, seeks to maximize the welfare of its citizens based on the quantity of goods and public services. Public good production utilizes the stock of capital, which increases through investment, and the level of current expenditures. The financing of current expenditures, investments, and financial expenses is achieved through taxes, grants, and potentially debt accumulation. However, this local government may be affected by a natural disaster which will destroy part of the municipality's capital. This shock will occur with a certain probability.

The objective is to understand the mechanism enabling the municipality to offset its capital loss. The planner will need to adopt strategies to restore the initial capital level. They may choose to raise taxes, potentially diminishing the utility of constituents, or resort to borrowing and accumulating debt.

Within this general framework, we analyze two types of situations: municipalities with the ability to incur debt and municipalities with debt constraints. In the first scenario, the reduction in the capital stock is instantly compensated by an increase in investment financed by debt. In the second scenario, where the financial health of the municipality does not allow for debt, the augmentation of investment to counteract the natural disaster is funded by taxes and a reduction in current expenditures.

Subsequently, we propose novel calibrations of this model using French data for these different configurations.

In the first two chapters, it is shown that municipalities need to increase their expenditures following a natural disaster and that these expenses will partly be financed by resorting to debt. Moreover, these budgetary effects appear to be persistent over time. Chapter 3 focuses on the effectiveness of prevention plans to mitigate the effects of natural disasters on municipal budgets.

Two methodologies are used to understand if prevention strategies have an effect on post-natural disaster budgetary reactions. Firstly, a Staggered Difference in Difference method is employed on two subsamples: one consisting of municipalities that had a prevention plan in place before a disaster struck and another consisting of municipalities that did not have a prevention strategy in place. The second method is a triple-difference approach, which identifies the additional effect on a budgetary account of experiencing a shock while having a prevention plan in the post-natural disaster period.

These estimations show that natural disaster prevention plans are effective in reducing the effects of natural disasters on municipal budgets. Indeed, it is observed

that municipalities that had implemented a prevention plan do not see a significant increase in their accounts compared to municipalities without a prevention plan.

However, this public policy, although effective in mitigating budgetary effects on local governments, does not seem to be accepted by citizens.

The second part of this chapter focuses on the effects of natural disasters and prevention policies on electoral outcomes at the municipal level. The objective is to understand whether the occurrence of a natural disaster or the implementation of prevention measures has positive or negative effects on the reelection of the incumbent mayor. To investigate this question, a Heckman model is employed to account for the possible selection bias arising from this situation. Therefore, it is necessary to take into account the individual decision to stand for reelection, which is made possible by a two-stage model.

The results show that experiencing a natural disaster has negative consequences on the probability of reelection. This voter behavior is called “blind retrospection”, meaning that voters punish their incumbents mayors for the bad times they have endured. On the other hand, the results show that the implementation of prevention strategies has a negative effect on mayoral reelection. This indicates that citizens seem to disagree with the implementation of such policies. Here, we observe a case of voter myopia, meaning that they do not see the future benefits of a policy in the long term and focus only on their short-term understanding.

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Chapter 1

Municipalities' budgetary responses to natural disasters

A french version of this chapter will be published as Morvan C. (2024). Les réponses des municipalités aux catastrophes naturelles. *Revue Economique*.

Abstract

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

1.1 Introduction

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

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

At the national level, several studies have examined the impact of disasters on central government finances. Noy & 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 & 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.

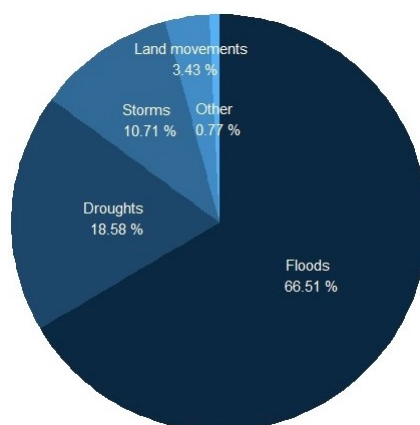
Masiero & Santarossa (2020) highlight a post-earthquake flypaper effect. They show that shock-specific grants boost government spending more than tax revenues and more than traditional grants.

On the other hand, some studies examine the reaction of local governments in the context of positive or negative shocks. Berset & Schelker (2020) focus on the impact of positive fiscal windfall. They show that municipalities increase permanently their expenditures which could lead to a fiscal windfall curse. Masiero & 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 & Wildasin 2006 ; Buettner 2009 ; Solé-Ollé & Sorribas-Navarro 2012).

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

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

Figure 1.1: 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.

1.2 Institutional context

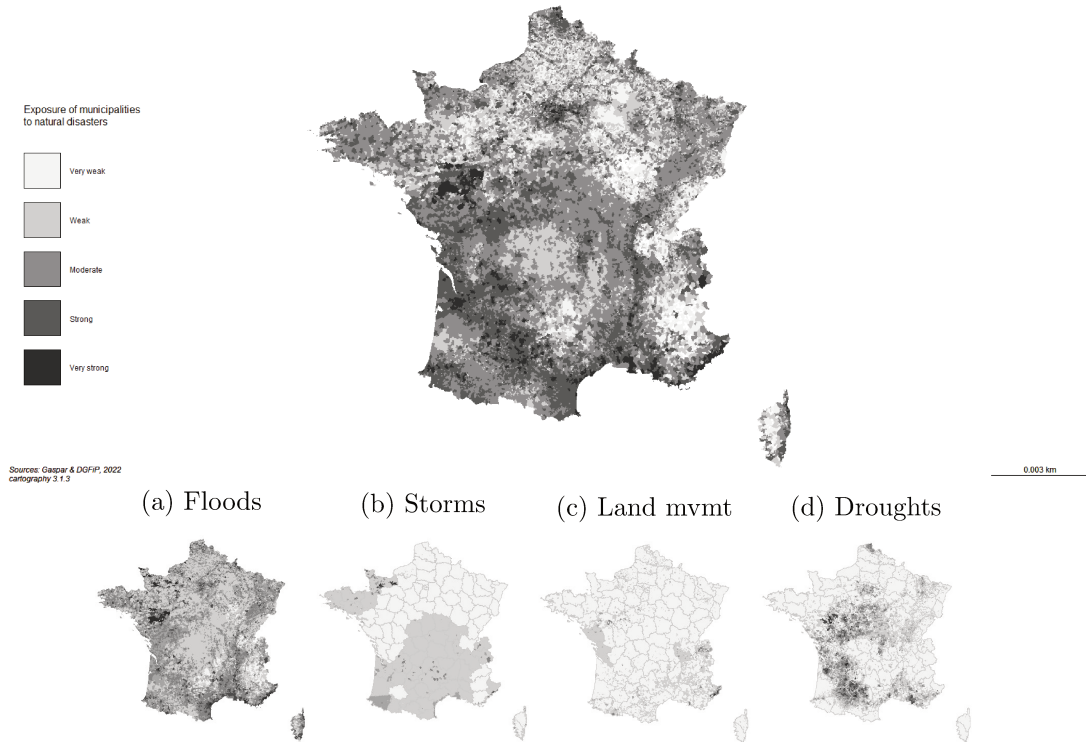
1.2.1 The particular features of natural disasters

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 environnement. Figure 1.1 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 and land movements. On average, more than 3000 natural disasters are recorded per year, i.e. 64,930 shocks since 2000. Figure 1.2 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 1.2a, 1.2b, 1.2c, 1.2d. I can notice that droughts affect mainly the center and the south west of France, while land movements are in the south east quarter of France. In addition, I can note that the floods although distributed on the whole territory, are more present along the rivers as well as on the coastal zones. As for the storms, I can notice that

they affect more the coastal regions.

Figure 1.2: Natural disasters in France 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. A very weak exposure means that no more than two shocks have affected this municipality, a weak exposure corresponds to a municipality that has suffered a maximum of 5 disasters, a moderate exposure includes 5 to 10 shocks, a strong exposure means an exposure of less than 20 shocks, while a very strong exposure shows a municipality that has experienced more than 20 climatic events. *Source* :Data on natural disasters were provided by the Ministry of Ecology. The cartographic data comes from the OpenStreetMap cartographic database made available by the DGFIP.

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 imple-

mentation of emergency services is the responsibility of the municipality such as transportation, emergency accommodation, communications (De Choudens 2015). The costs are initially current expenses, then can be capital expenditures in a second time.

The issue of natural disasters is also current in France since a new law on compensation for natural disasters has been enacted in December 2021, to make the procedures more transparent and more efficient. The main changes are: the inclusion in the law of the role of the interministerial commission that makes annual assessments and statements on the reference systems used to assess the abnormal intensity of natural phenomena. In addition, a national consultative commission on natural disasters is created and whose objective will be to re-evaluate the criteria of natural disasters, as well as a group of referent to help municipalities in the administrative steps. Finally, the time limit for declaring a damage is extended to 2 years and the time limit for reimbursing the victims is shortened¹.

1.2.2 Administrative organization: governments' roles and grants

This study on the impact of natural disasters on local government budgetary decisions uses French data that allow us to analyze this issue, but this requires attention to the specific institutional context. A particularity of France is that it has about 35,000 municipalities, more than half of them have less than 500 inhabitants and more than 80% have less than 2000 inhabitants. These tiny jurisdictions create a particular institutional context, especially with regard to politics.

On the other hand, it is important to note that France is a decentralized country with several levels of government: the central government, regions, counties (departments), inter-municipal cooperation (EPCI) and municipalities. Each level of government has specific competencies. The municipalities are responsible for local roads, schools, sports and cultural facilities, parks and gardens, maintenance of sewage systems, and waste treatment. The counties are responsible for rural roads, ports, colleges, museums, and are also involved in other areas such as childhood, disability, the elderly, and social assistance. The regions are responsible for national parks, river ports, airfields, high schools, they also finance infrastructure, railroads. The distinction between the roles of each level of government is important because during natural disasters, the management of the infrastructure is the responsibility of the one on which it depends, i.e. the renovation of a museum will be the responsibility of the county, while that of a school will be the responsibility of the municipality.

The mayors are also responsible at the time of the crisis for the safety of the population, the preparation and the organization of the rescue. In the event of a

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

crisis, the roles of each local authority are sometimes intertwined, which can cause certain difficulties. However, the mayors of the municipalities concerned remain responsible for the safety of the population.

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

For costs related to the damage caused by the disaster, municipalities may be assisted in 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 Code des Assurances², 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 jurisdiction³. In addition, when a natural disaster decree is issued, local authorities that are beneficiaries of the Value Added Tax Compensation Fund (FCTVA)⁴ can obtain a refund of the VAT for investment expenses (Requillart 2014). Finally, other grants can be requested to carry out investment work, such as the local investment support grant (DSIL) or the rural territory equipment grant (DETR), if the municipalities meet the criteria. (Maurey 2019).

1.3 Data

To create the database for this study, which includes 34,627 municipalities between 2000 and 2019, I use several sets from different institutions. The first set is the database of French municipal accounts between 2000 and 2019 available from the

²article L.125-1 of the Code des Assurances

³article R.1613-9 of the code général des collectivités territoriales

⁴article L.1615-6 III of the code général des collectivités territoriales

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 A.2 in the appendix for all indicators).

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

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

1.4 Methodology

1.4.1 Difference in Difference approaches

Two-ways Fixed Effect model

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

$$Y_{i,t} = \sum_{\tau=0}^{12} \beta_{\tau} Shock_{i,\tau} + X_{i,t}\gamma + \mu_i + \theta_t + \varepsilon_{i,t} \quad (1.1)$$

The dependent variable $Y_{i,t}$ is the logarithm⁵ of one municipality's account, which can be current expenditures, capital expenditures, total expenditures or other sub-accounts. Our main variable of interest is the variable $Shock_{i,\tau}$ which represents the natural disaster, it is a dummy variable equal to 1 when the disaster occurs, i.e. $Shock_{i,0} = 1$ the year that municipality i is affected by a natural disaster and

⁵The 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.

$Shock_{i,1} = 1$ if municipality i has been affected by a natural disaster last year. I also consider a vector of municipal characteristics $X_{i,t}$, which includes several time-varying financial, socio-demographic, socio-economic and institutional covariates as well as time-invariant variables about their environmental situation. Specifically, these are the logarithms of operating grants and subsidies received by the central government, tax revenues and loans of municipalities. The political and institutional variables are the number of years before the next election, the type of inter-municipal cooperation and the region to which the municipality belongs. The socio-economic and socio-demographic variables are the size of the population, the logarithm of the median income per capita, the share of unemployed in the municipality's population, the share of people under 20 years old and the share of people over 65 years old.

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

A random effects model has the advantage of providing a consistent and efficient estimate when the model assumptions are satisfied. It also controls for time-invariant observed factors. Nevertheless, the assumptions of this model are demanding, and the estimate becomes spurious if the assumption of independence of time-invariant errors is violated. The chosen model is, therefore, a fixed effect regression. I decided to exclude pooled OLS and random effect regressions, as they do not address unobserved time-invariant heterogeneity. This choice is supported by both pooling and Hausman tests. The selected fixed effect estimator is the within estimator, allowing us to retain more information compared to a first difference or between estimator. Additionally, White's robust covariance matrix enables us to control for heteroscedasticity and serial correlation.

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

The second problem could result from the fact that the shock may also impact certain regressors. For example, a natural disaster may be assumed to have an effect

on residents' income. In this case, the shock coefficient could be biased. To test this endogeneity issue, I estimate the model with and without control variables. I do not observe a significant difference between the two estimations; they both align in the same direction.

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

Another point concerns a confounding factor that could bias the estimation. An unobserved factor may have an effect on both the occurrence of a natural disaster and municipal expenditures. For example, if a municipality chooses to build infrastructure along a river in a potentially dangerous area, this could increase the risk of flooding and still constitute a municipal expense. Conversely, a municipality wishing to limit its expenses may choose to maintain its river facilities less regularly, affecting the risk of a disaster. To mitigate this endogeneity problem, I could check for the existence of a risk prevention plan in the municipality. The objective of such a plan is largely to raise awareness of disaster risks in a municipality and to delineate potentially risky areas to limit constructions, among other measures. These decisions could introduce a bias into the observation of the disaster⁶. We, therefore, add prevention plans as control variables. This is a dichotomous variable equal to 0 if there is no prevention plan and equal to 1 when a prevention plan is created and active in the respective years. The addition of this control variable does not change the results presented in the following section. However, a second issue arises since natural hazard prevention plans (NHPP) also pose an endogeneity question. Indeed, a NHPP is endogenous to both past shocks or a municipality's exposure to risk and probably to the intensity or cost of future shocks suffered, as the purpose of a prevention plan is to limit the impact of a shock. This reverse causality problem is a real limitation of this analysis and would require an ad hoc identification method to overcome it.

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

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

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

Staggered Difference in Difference

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

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

$$Y = \alpha_1^{s,t} + \alpha_2^{s,t} Shock_s + \alpha_3^{s,t} \mathbf{1}\{T = t\} + \beta^{s,t} (Shock_s \times \mathbf{1}\{T = t\}) + \gamma \mathbf{X} + \varepsilon^{s,t} \quad (1.2)$$

The outcome variable Y is one municipality’s account per capita which can be total expenditures, revenues, grants or other subaccounts (current expenditures, investment expenditures, tax revenues, etc.) The variable $Shock$ represent the natural disaster, which is equal to 1 if the municipality i is first treated in period s , i.e $Shock_{i,s} = \mathbf{1}\{Shock_i = s\}$. I also consider a vector for municipal characteristics \mathbf{X} , which includes several time-varying financial, socio-demographic and socio-economic covariates. Specifically, these are the logarithms of the municipality’s debts and tax revenues. The socio-economic and socio-demographic variables are population size, share of people aged under 20 years, and the share of people aged over 65 years.

To analyze the effects of a natural disaster on the municipal budget, I use a

special aggregation scheme which provides an understanding of how the average treatment effect evolves with the length of time of exposure to the treatment, i.e. event-study-type estimates.

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

1.4.2 Panel Vector Autoregression Model

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

$$Y_{i,t} = \alpha_0 + \alpha Y_{i,t-1} + \sum_{j=0}^5 \beta_{\tau-j} Shock_{i,\tau-j} + \mu_i + \theta_t + \varepsilon_{i,t} \quad (1.3)$$

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

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

1.5 Results

1.5.1 Impact of natural disasters on the main municipal budget accounts

Fixed Effect Model

Table 1 reports the results of regressions based on the model of Equation (1.1). The objective here is to understand the disaster effect on the main accounts of municipalities. The dependent variables are total expenditures, total revenues, total subsidies, and debt in columns 1, 2, 3, and 4, respectively.

The first observation is a significant increase in total expenditures in the year of the natural disaster⁷, as well as in the three years following the shock. The impact of the natural disaster is approximately 0.7% to 0.5% per year up to 3 years after it. The second column shows estimates based on the logarithm of total municipal revenues. I observe a significant increase in revenues after a natural disaster, with a rise of 0.7% in revenues in the year of the shock and up to 2 years after the disaster. These results indicate that the shock has a direct effect on revenues, which does not seem very persistent over time. The third column presents estimates of the effects on total subsidies, i.e., the sum of operating grants and investment grants. These results show a significant increase in grants between the second year and the fourth year after the shock. This indicates that the increase in total revenues during the disaster is not due to a significant increase in subsidies from higher-level governments. Furthermore, the increase in subsidies between $t - 2$ and $t - 4$ does not cause a significant increase in total revenues. Finally, the fourth column shows estimates of the impact on debt. This column shows a 3.3% increase in debt at the time of the natural disaster. This is a strong impact that persists up to 4 years after the shock.

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

Staggered Difference in Difference

The figure 1.3 reports the results of the regressions based on the model of the equation (1.2). The objective here is to understand the causal relationship of the occurrence of a shock to the main accounts of municipalities. The dependent variables

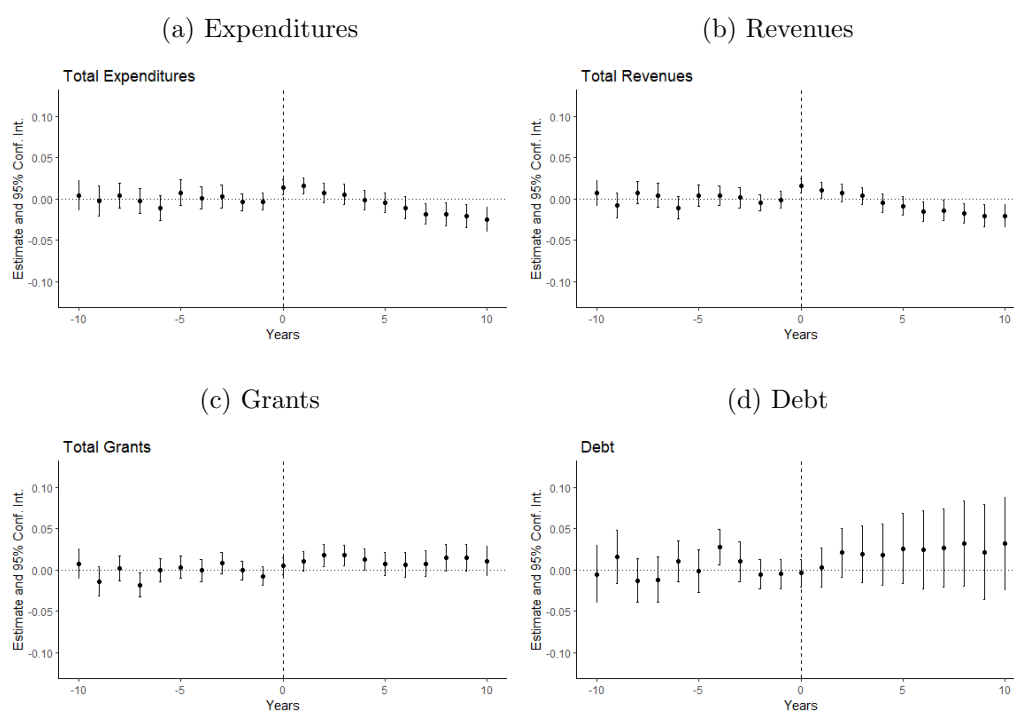
⁷The year t represents the year when the shock occurred, the year $t - 1$ is the following year, and so on up to $t - 10$, which represents the 10th year after the occurrence of the disaster. If a municipality experiences multiple natural disasters, the count restarts with each new shock.

Table 1.1: Impact of natural disasters on main municipal accounts

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

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

Figure 1.3: Effect of a natural disaster on the main budget accounts



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

are total expenditures, total revenues, total grants and debt, figure 3.5.1a, 3.5.1b, 3.5.1c and 1.3d respectively. The control group is composed of 12,184 municipalities that did not experience any natural shocks. The treatment group includes the 21,898 municipalities that had at least one shock between 2000 and 2019. However, until the first shock occurred, the municipality belongs to the control group.

Figure 3.5.1a shows a significant increase in total expenditures at the event of the natural disaster and the year after. The increase in total expenditure at the time of the shock seems to indicate the need for emergency spending. On the other hand, I have observed a reduction in this spending 7 years after the disaster. This indicates that municipalities are not maintaining their pre-disaster public spending levels.

Indeed, I can see from the figure 3.5.1b that the revenues react in the same way. Municipalities saw their revenues rise at the time of the shock, then decline 7 years afterwards.

This represents the key distinction observed in comparison to the earlier estimation. By considering the timing variability of natural disasters, this methodology

has enabled the identification of a long-term negative impact on expenditures.

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

Figure 3.5.1c shows the effects of natural disasters on total grants. I find that municipalities experience a significant increase in the amount of state grants during three years after the shock, likely due to the compensation to fund expenditure on recovery.

Finally, the figure 1.3d shows the effect on the municipal debt. Despite the positive coefficients, I find no significant effect of natural disasters on debt.

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

Panel Vector Autoregression Model

The figure 1.4 shows the dynamic responses of the PVAR model estimate of equation (1.3) (Table A.3 in appendix presents the point estimates of the DMFs).

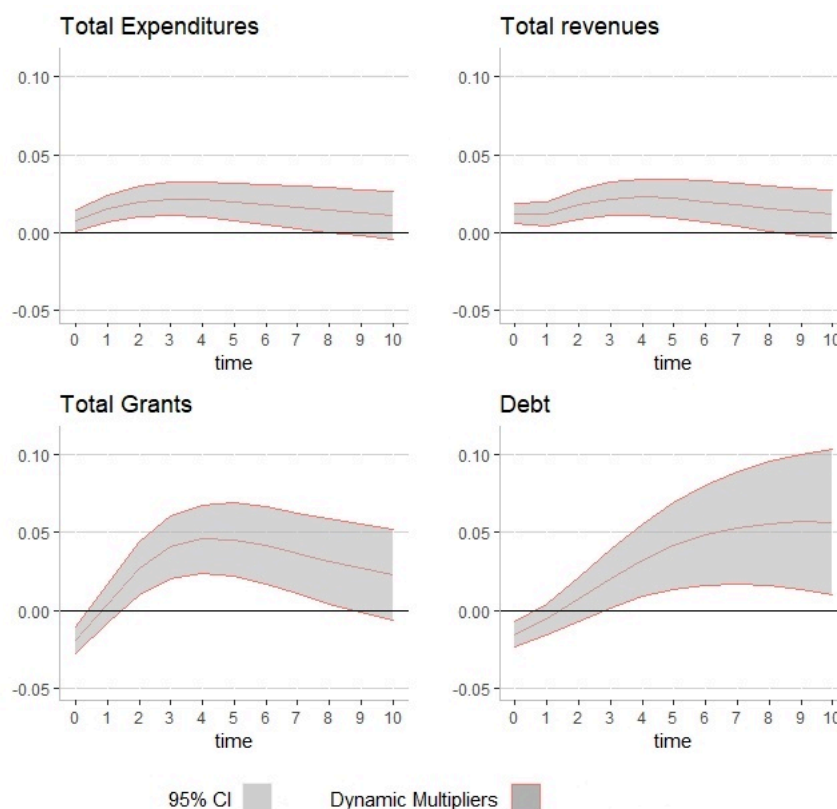
The estimated points represent the variation of the different variables following the occurrence of a natural disaster. As expected, the figure 1.4 shows a significant increase in total expenditures (top left) at the time of the shock. Expenditures increase up to 4 years after the disaster, and then growth declines in the longer-term post-shock period, which is consistent with the results of the previous estimate. This increase is significant in the 7 years after the shock, i.e. the effect is more persistent than in the previous estimate.

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

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

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

Figure 1.4: Dynamic response of main accounts to natural disaster



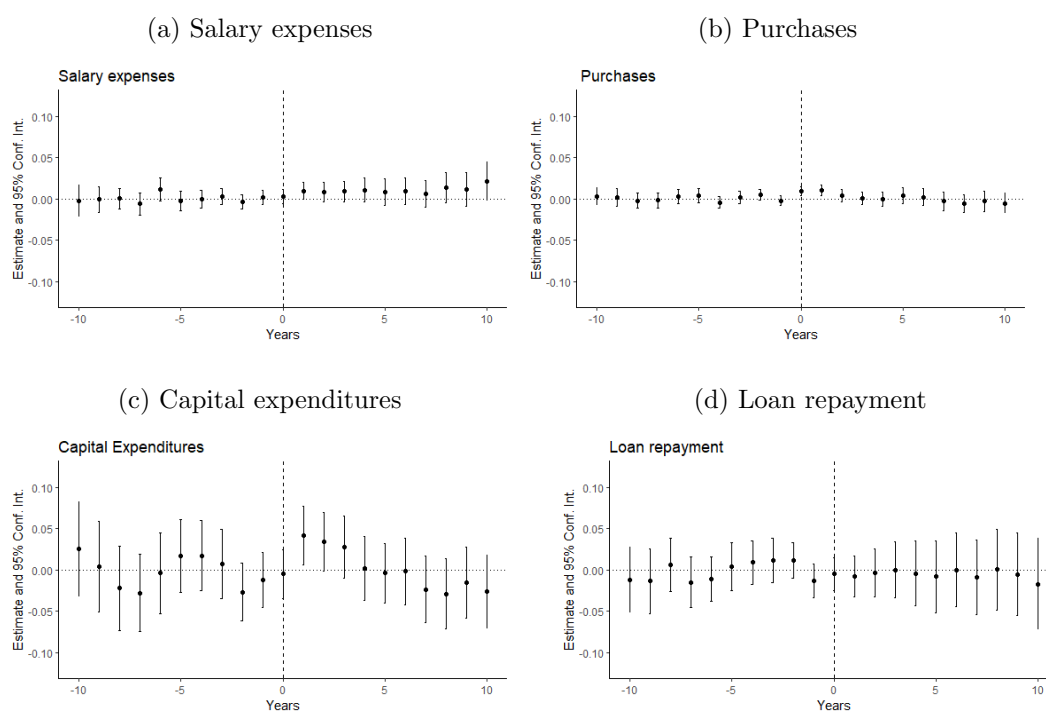
Notes: These figures show the DMFs of debt, total revenues, total grants and total expenditure. Values on the x-axis indicate years after the shock, The y-axis represent the change in the account of the local government. Shaded area indicates the 95 percent confidence interval for the relevant dynamic 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.

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

1.5.2 Impact of natural disasters on the sub-accounts

The results of the budget sub-accounts showed that expenditures increased after the occurrence of a shock. These results made wonder about the types of expenditure that are involved in this increase. Figure 1.5 shows the effect of natural disasters on salary expenditures, current purchases, capital expenditures and loan repayments, in order to understand more precisely the effects of a natural disaster on the budgetary choices of municipalities.

Figure 1.5: Effect of a natural disaster on the expenditure sub-accounts



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

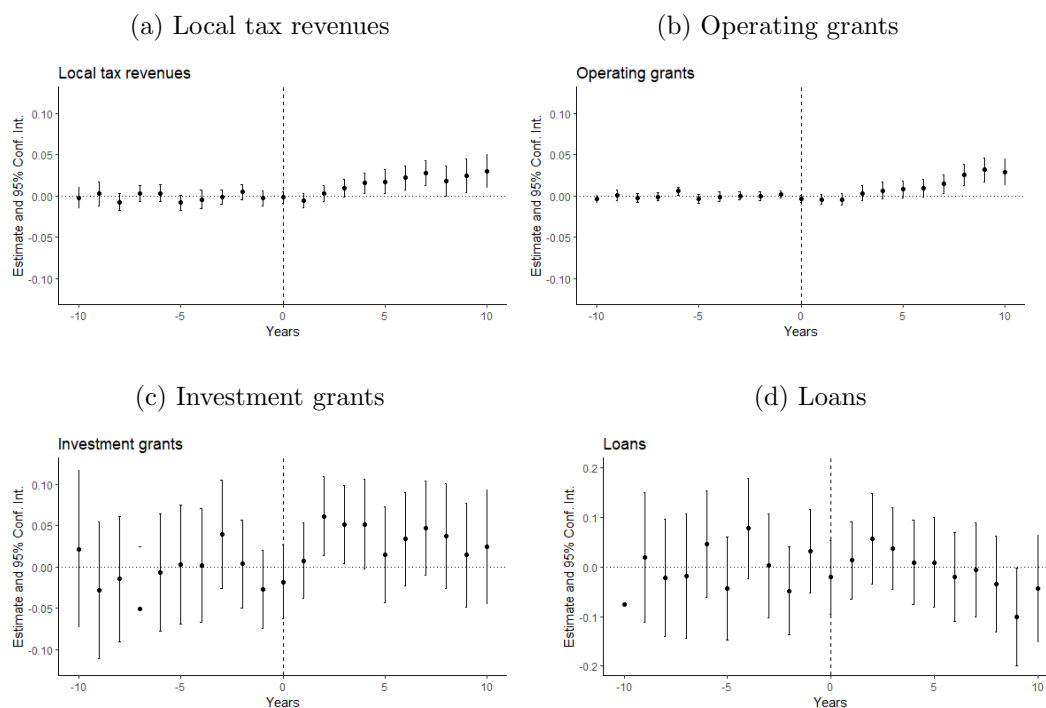
Figure 1.5a and 1.5b concern current expenditure. Thoses figures show that salary expenses increase significantly in year after the shock and purchases increase in the event of the disaser and the year after.

Figure 1.5c and 1.5d are part of investment expenditures. Capital expenditures considered here are only for the acquisition of new capital, not for repair costs. I observe here an increase 2 years following the disaster, which means that municipalities are able to finance new investments. Concerning loan repayments, I don't observe any significant effect.

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

On the other hand, I examine the extent to which municipal revenue levers are affected by a shock. These levers are of different types, first operating grants 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 municipal-

Figure 1.6: Effect of a natural disaster on the revenue sub-accounts



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

ities. In the accounts of the municipalities, operating grants and tax revenues are considered as current revenues (Figures 1.6a and 1.6b) and investment grants and loans are investment revenues (Figures 1.6c and 1.6d).

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

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

Finally, the figure 1.6d shows the effect of natural disaster on contracted loans. I observe a significant decrease the 9th year after a disaster. This means that the municipalities reduce their loans after the 9th year.

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

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

1.5.3 Financial health: A key factor in recovery

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

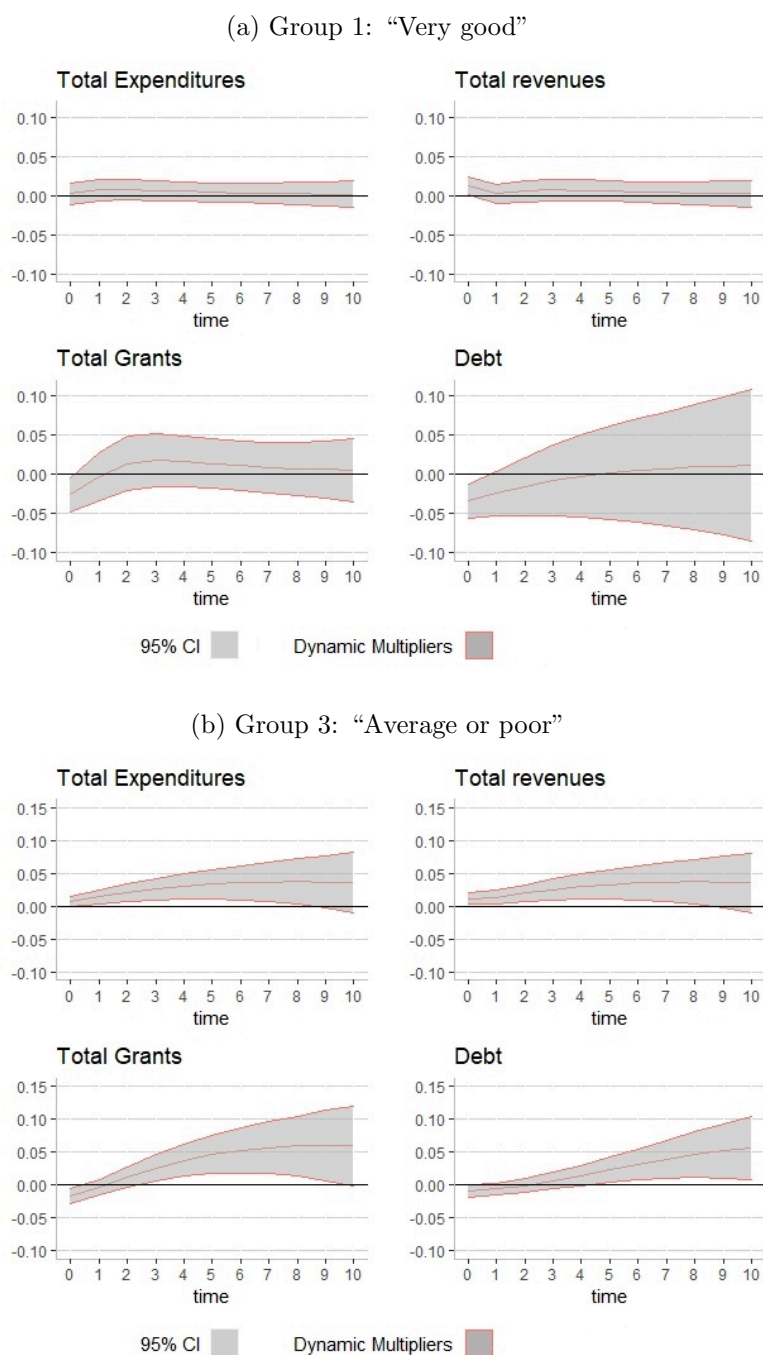
To achieve this, I use a financial health rating established by the Agence France Locale (AFL). This AFL rating serves as an indicator of the sound budgetary functioning of local authorities. It is calculated based on various indicators such as debt, self-financing capacity, and savings. This rating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

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

I then apply the dynamic PVAR model described in Section 1.4.2 to compare the reactions of the different groups.

The figures 1.7a and 1.7b present the results of the analyses on the different rating groups. I focus our analysis on groups 1 and 3 (Descriptive statistics and other results are available in the appendix section ??). The results first show significant differences between group 1 and group 3. In the first group, i.e., municipalities with a very good average financial health, the impact of natural disasters is low. The effect of the shock on the main accounts of the municipalities, although significant

Figure 1.7: Dynamic response of main accounts to natural disaster: by financial health groups



Notes: These figures show the DMFs of debt, total revenues, total grants and total expenditure. Values on the x-axis indicate years after the shock, The y-axis represent the change in the account of the local government. 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.

at the time of the shock, is not persistent. I observe no long-term effect for these municipalities, as well as no impact on debt. This suggests that financially healthy municipalities can easily recover from a natural disaster, possibly by utilizing their own resources.

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

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

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

1.5.4 Robustness Checks

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

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

Clearly, there is no significant effect in the pre-shock periods on the graphs 3.5.1a, 3.5.1b, 3.5.1c and 1.3d. I also perform the TWFE regressions as for the baseline results by observing the year prior to the shock, to detect a possible effect (appendix table A.7) The results of this test show that there is no significant effect on municipal accounts in the year before the shock. Moreover, the common trend hypothesis is verified from Figure C.1 in Appendix. For this purpose, I observe the pre-shock trends for the control and treatment groups.

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

I then estimate the DiD model by considering only these extreme events, and observe results of a similar magnitude to the baseline (see figure A.12 in Appendix).

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

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

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

of the population and cause material damage, while a drought will mainly affect agriculture and health, which does not cause the same costs for the municipalities.

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

1.6 Discussion and conclusion

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

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

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

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

At the time of a natural disaster, tax revenues may be impacted. It is expected that tax revenues will decrease due to a fall in tourism in the municipality and the

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

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

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

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

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

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

for a detailed identification of effects and mechanisms.

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

This constitutes the proposition outlined in Chapter 2 of this thesis.

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A Appendix

A.1 Descriptive statistics

Table A.2: Descriptive statistics of municipal accounts

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

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

A.2 Additionnal results

PVAR

Table A.3: Dynamic impact of natural disaster on local governments main accounts

	year τ	$\tau-1$	$\tau-2$	$\tau-3$	$\tau-4$	$\tau-5$
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)
	$\tau-6$	$\tau-7$	$\tau-8$	$\tau-9$	$\tau-10$	
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.

Sub-accounts : Expenditures

Table A.4: Impact of natural disaster on local government expenditures - sub-accounts

<i>Fixed Effect model - Within Estimator</i>				
	Current Expenditure		Investment Expenditure	
	Salary expenses	Purchases	Capital expenditure	Loan repayment
Shock _{τ}	0.002 (0.005)	-0.001 (0.005)	0.0005 (0.008)	0.057*** (0.013)
Shock _{$\tau-1$}	0.008* (0.004)	0.001 (0.005)	0.030*** (0.009)	0.072*** (0.015)
Shock _{$\tau-2$}	0.004 (0.005)	-0.004 (0.004)	0.026* (0.016)	0.090*** (0.015)
Shock _{$\tau-3$}	0.007 (0.006)	-0.004 (0.005)	0.024** (0.011)	0.111*** (0.018)
Shock _{$\tau-4$}	0.007 (0.006)	-0.005 (0.005)	-0.002 (0.021)	0.106*** (0.020)
Shock _{$\tau-5$}	0.004 (0.006)	-0.002 (0.005)	0.001 (0.016)	0.105*** (0.023)
Shock _{$\tau-6$}	0.015** (0.006)	0.0005 (0.005)	0.004 (0.008)	0.097*** (0.023)
Shock _{$\tau-7$}	0.001 (0.006)	-0.002 (0.003)	-0.002 (0.023)	0.072*** (0.021)
Shock _{$\tau-8$}	0.008 (0.006)	-0.009*** (0.002)	-0.023 (0.025)	0.049* (0.025)
Shock _{$\tau-9$}	0.007 (0.006)	-0.003 (0.003)	0.007 (0.026)	0.074*** (0.022)
Shock _{$\tau-10$}	0.010 (0.008)	-0.004 (0.004)	0.013 (0.024)	0.050 (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 unemployment) 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.

Sub-accounts : Revenues

Table A.5: Impact of natural disaster on local government revenues - sub-accounts

	<i>Fixed Effect model - Within Estimator</i>			
	Current Revenue		Investment Revenue	
	Local taxes	Operating Grant	Investment grants	Loans
Shock _τ	0.003 (0.003)	-0.008** (0.004)	0.055*** (0.016)	-0.003 (0.029)
Shock _{τ-1}	0.001 (0.003)	-0.013*** (0.005)	0.066*** (0.018)	0.025 (0.032)
Shock _{τ-2}	0.011*** (0.003)	-0.001 (0.004)	0.067*** (0.019)	0.063* (0.035)
Shock _{τ-3}	0.014*** (0.003)	-0.001 (0.005)	0.078*** (0.021)	-0.003 (0.037)
Shock _{τ-4}	0.014*** (0.003)	0.002 (0.005)	0.032 (0.022)	-0.052 (0.040)
Shock _{τ-5}	0.015*** (0.004)	0.012*** (0.005)	-0.001 (0.024)	-0.072* (0.042)
Shock _{τ-6}	0.019*** (0.004)	0.010* (0.005)	-0.002 (0.026)	-0.187*** (0.045)
Shock _{τ-7}	0.019*** (0.004)	0.013** (0.006)	0.016 (0.028)	-0.122** (0.048)
Shock _{τ-8}	0.020*** (0.004)	0.024*** (0.006)	-0.064** (0.030)	-0.182*** (0.050)
Shock _{τ-9}	0.013*** (0.005)	0.019*** (0.007)	-0.013 (0.031)	-0.244*** (0.054)
Shock _{τ-10}	0.018*** (0.004)	0.015** (0.007)	-0.029 (0.034)	-0.055 (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

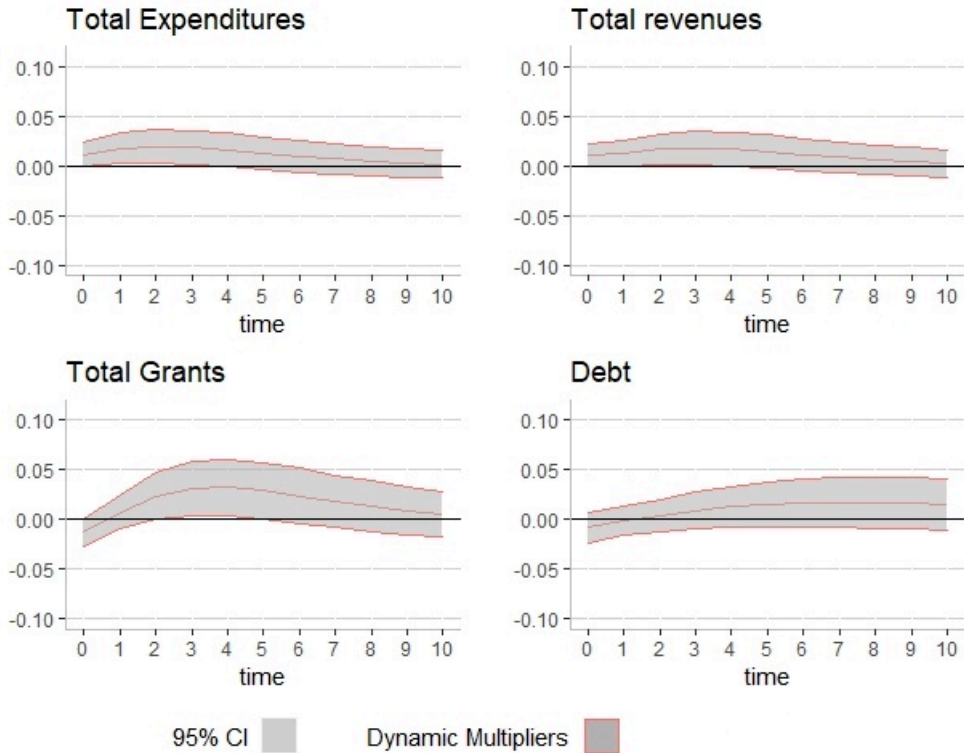
Note : *p<0.1; **p<0.05; ***p<0.01 ; All models control for financial time-variant characteristics (current and investment expenditures and revenues), political (years before elections), institutional (type of inter-municipal cooperation, state fixed effect), socioeconomic (median income and percent of unemployment) 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.

Financial health

Table A.6: Descriptive statistics of different level groups

	Minimum	Mean	Median	Maximum	Obs
Panel 1: <i>VERY GOOD</i> ($1 < Grade < 2.5$)					9491
Expenditures	108.20	1121.52	895.78	33587	
Revenues	116.78	1388.28	1123.43	33835	
Nb. Shocks	0.00	1.22	1.00	14.00	
Panel 2: <i>GOOD</i> ($2.5 < Grade < 4$)					16735
Expenditures	127.07	1127.76	917.84	34990	
Revenues	9.39	1299.18	1069.14	35227	
Nb. Shocks	0.00	1.47	1.00	13.00	
Panel 3: <i>AVERAGE or POOR</i> ($4 < Grade < 7$)					7936
Expenditures	233.35	1306.70	1097.23	53324	
Revenues	236.58	1427.69	1207.45	54025	
Nb. Shocks	0.00	2.23	2.00	15.00	

Figure A.8: Dynamic response of main accounts to natural disaster by financial health groups: Group 2: “Good”



A.3 Robustness Checks

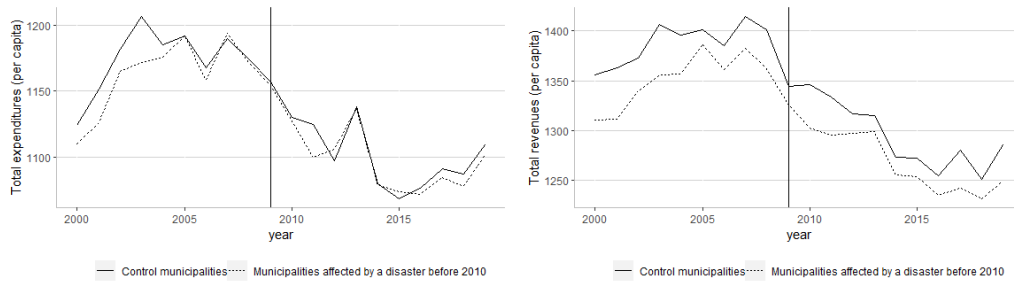
Placebo test

Table A.7: Impact of natural disaster on local government expenditures: Placebo Test

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

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

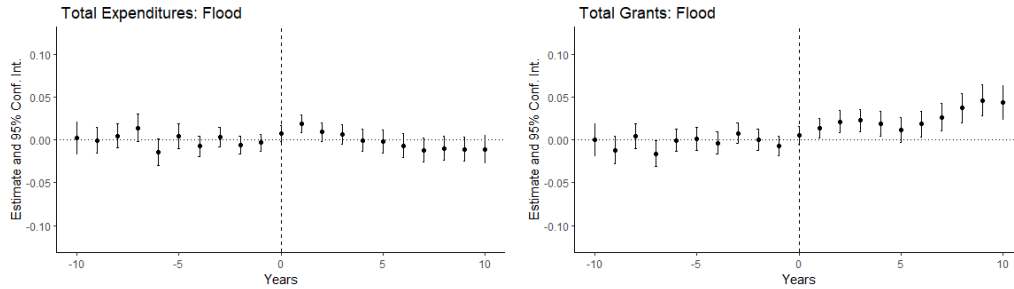
Figure A.9: Impact of natural disaster on local government expenditures: Common Trend



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

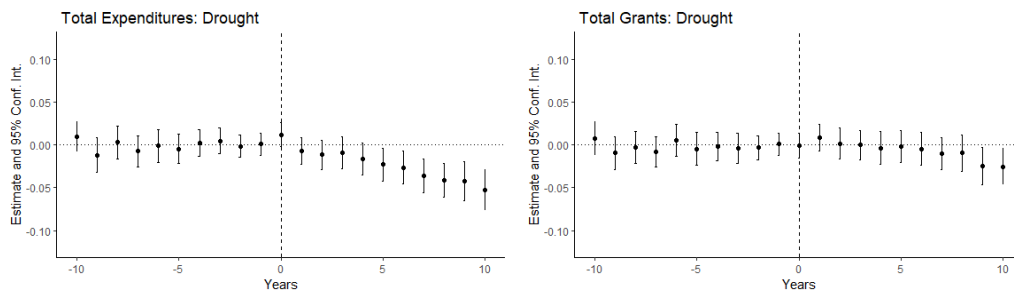
Type of shocks

Figure A.10: Impact of natural disaster by type of shocks: Flood



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

Figure A.11: Impact of natural disaster by type of shocks: Drought



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

Sensitivity and Intensity analysis

Table A.8: Sensitivity analysis of the impact of natural disasters on local government expenditures

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

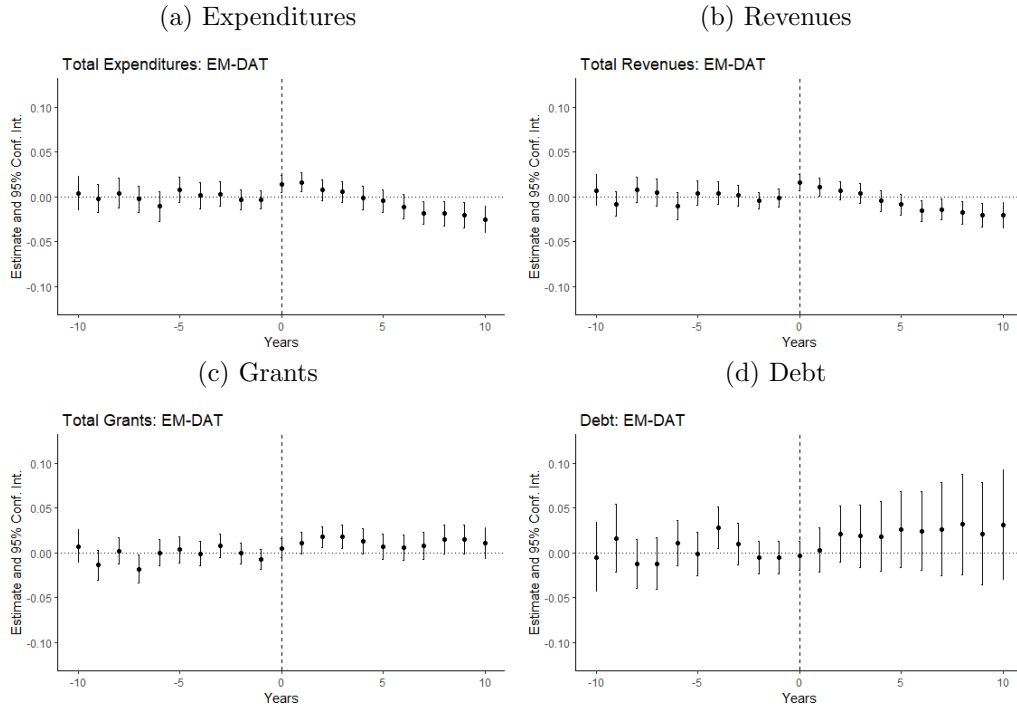
Note: $p < 0.1$; $p < 0.05$; $p < 0.01$; All models control for financial characteristics (local tax and grant revenues), political factors (years before elections), institutional features (type of intermunicipal cooperation), socio-economic factors (median income and percentage of unemployed), and sociodemographic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

Table A.9: Impact of natural disasters on local government expenditures using different disaster frequency measures

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

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

Figure A.12: Effect of a major natural disaster on the main budget accounts



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

Chapter 2

Optimal Management of Local Budget subject to Capital Shocks

This chapter is based on a paper co-authored with Frédéric Jouneau*.

Abstract

We present a theoretical framework to explore the consequences of natural disasters on municipal financial aggregates. In our model a local benevolent decision-maker dynamically maximizes the welfare of its fellow citizens, under exogenous shocks. We focus on the occurrence of natural disasters that destroy part of a local capital stock. We highlight how the optimal response is linked to financial capacity of the local government. More precisely, we perform simulations under fully constrained and totally unbounded access to borrowing. These simulations are performed using calibration derived from a French panel data set covering yearly financial data from 2000 to 2019 over 10.000 municipalities. In both cases, we investigate optimal responses to natural disasters shocks in both cases for investment, local expenditure, debt. We quantify the relative welfare consequences and the speed of recovery between constrained and unconstrained municipalities.

*Professor of Economics, Université Lyon 2, GATE Lyon Saint-Étienne

2.1 Introduction

Natural disasters are phenomena that impact all territories and may increase in the context of climate change. Beyond direct causalities, natural disasters often generate significant costs for municipalities, severely damaging roads, bridges, and power, water and communication networks. Recent dramatic floods in several European countries¹ have shifted the focus of the natural disasters debates from a Worldwide perspective (widely publicized by IPCC reports) to a more local level. The effectiveness of local government policies in preventing and mitigating the consequences of natural disasters has begun to receive more attention.

The theoretical microeconomics literature emphasizes the importance of interactions between different levels of government. Indeed, institutions provides local decision makers with some *de jure* or *de facto* broad insurance against natural disasters, the incentive to prevent the consequences will be weak at the local level, resulting in under-investment and more severe consequences (see Goodspeed (2013)’s review). This argument sounds particularly relevant for France who witnesses a highly intricate combination of levels of public interventions (the famous French “mille-feuille”, see Gerbeau (2024)). However, empirical results show that central governments do not provide complete insurance and local one must rely on their own resources to compensate for the damages incurred (Morvan (2022) ; Miao, Hou, et al. (2018)).

The empirical literature also studied the impact of natural disasters on local government budgets. Some studies demonstrate the long-term effects of natural hazards on local budgets, including Jerch et al. (2023) in the South USA, Morvan (2022) in France, Masiero & Santarossa (2020) in Italy, Miao, Chen, et al. (2020) in China, Panwar & Sen (2020) in India, and Miao, Hou, et al. (2018) in US States. While the majority of studies indicate an increase in expenditures and revenues at the time of the natural shock, they do not all agree on the long-term effects. This is mainly due to the challenging task to identify the mechanisms and causal pathways from shock to reactions of local governments. Indeed, the actual policies schedules can spread over several years and dynamic interactions hamper implementation of quasi-experimental econometric techniques.

Dynamic interaction following disasters are then most studied at the macro level. A vast body literature examines the impact on growth or welfare (see the systematic review by Botzen et al. (2019) and Kousky (2014)).

Empirical articles specifically focus on the effects of natural disasters on public expenditures at the national level. Noy & Nualsri (2011) conducted a comparative study encompassing 42 developed and developing countries to comprehend the

¹At the end of 2023, 265 municipalities in northern France were declared in a state of natural disaster following repeated floods. The major rainfalls in 2021 caused several hundreds of deaths all over Northern Europe.

budgetary responses of states following natural disasters. Their findings reveal that developing countries tend to exhibit pro-cyclical behavior, whereas developed countries tend to adopt counter-cyclical behavior. In other words, in developing countries state increases expenditures and decrease taxes after a shock. Melecky & Raddatz (2011) demonstrate that developed countries experience less impact from natural disasters, even though they witness an increase in their deficits. The authors also identify a correlation between higher levels of insurance protection and lower consequences of the disaster in terms of deficits.

The theoretical literature, focusing on the effect of shocks on public finances, shows that the optimal government response is to smooth fiscal or budget fluctuations over time (Barro (1979) ; Lucas & Stokey (1987)). However, we are not aware of a specific study regarding consequences of natural disaster.

Our approach borrows from the macro-literature on rational expectation models, as we derive the optimal response of a local government to a natural disaster shocks. But we also give credit to the public economic literature by assuming our local benevolent decision maker maximizes the welfare of its fellow citizens through provision of a local public good. Finally, in continuity of theoretical literature that, since "The Economics of Natural Disasters" by Dacy & Kunreuther (1969), we model a natural disaster as a loss of capital stock (Okuyama (2019) ; Albala-Bertrand (1993)). However, our focus is not on growth but on the short run effects of a capital shock on local government budgets.

Our model provides dynamic patterns for various local financial accounts, including investment, debt level, local expenditures, and taxes revenues. We highlight the role of financial capacities in the management of such crisis. While unlimited borrowing ability lead to quick recovery (at the price of an everlasting higher debt level) more stringent constraints – as documented by Vammalle & Bambalaite (2021) – lead to a trade-off between increasing taxes and lowering public expenditures, echoing some of the empirical findings by Noy & Nualsri (2011) mentioned above.

Incidentally, we argue our theoretical findings could help enlighten public decision-makers and banks on a more general level. Indeed our model provide justifications – as well as limits – for some financial ratios that are often used by public accountant as well as bankers to assess financial stability. In this respect, we also contributes to the literature on the influence of climate change on municipal debts, which shows that natural risks have negative effects on municipal debts by altering banking fees and downgrading municipalities (Jerch et al. (2023) ; Painter (2020)).

We apply this model to the French case, which displays several specificity. In this country, the most local level of public government consisting of 36,000 municipalities. This allows for a detailed geographical study, giving rise to a large sample observations at the local level. It also presents significant heterogeneity among these

local government levels in particular regarding wealth, population size and capacities. Our panel database covering all French municipalities over a 20-year period, enable us to exploit this heterogeneity.

The remainder of this article is structured as follows. The second section presents the model. Section 3 and 4 presents the data and the calibration. Section 5 presents the simulations results. The final section concludes.

2.2 The model

We consider a single, isolated municipality in which a benevolent planner chooses the level of investment, current expenditures, debt, and taxes, under budget constraint. The objective of the local decision-maker is to maximize the utility of the residents. Each citizen consumes two goods: (i) a public good delivered in a fixed quantity q provided (s)he complies with a flat tax T , and (ii) a private good with unitary price p . As the disposable after-tax income equal private consumption expenditure the indirect utility of a resident is :

$$V = q \left(\frac{R - T}{p} \right)^\mu$$

Notice that unlike a conventional indirect utility function, only the price of the private appears in the above equation as the public good is provide to any citizen in the same, fixed quantity.

For the year t , let's denote:

Variable	Description
Y_t	Quantity of public goods produced by the municipality
T_t	Municipal tax levied
G_t	Current expenditures (volume of.)
I_t	Investment expenditures (volume of.)
K_t	Capital stock of the municipality (public infrastructure, amenities)
B_t	Accumulated debt stock at the end of period t
S_t	Grants provided by central government for the accounting year t
R_t	Income of the representative citizen
ϕ_t	Nominal price current expenditures
θ_t	Nominal price investment
ϵ_t^K	Natural disaster shock
r_t	Interest rate

Assuming functional choices directly borrowed from the macro-economic literature, we formulate the problem of the municipal planner as follows:

$$\left\{ \begin{array}{l} \max \quad E_0 [\sum_t \beta^t \log(V_t)] \\ \text{s.t.} \quad T_t + S_t + B_t - B_{t-1} = \phi_t G_t + I_t + r_{t-1} B_{t-1} \\ \quad \quad Y_t = A_Y K_{t-1}^\alpha G_t^{1-\alpha} \\ \quad \quad K_t = (1 - \delta) K_{t-1} + I_t + \epsilon_t^K \\ \quad \quad V_t = Y_t \left(\frac{R_t - T_t}{p_t} \right)^\mu \end{array} \right.$$

In our model, all citizens are identical. Therefore, it is entirely equivalent to consider that the objective is to maximize the welfare of a representative consumer or the sum of the welfare of all residents. However, maximizing the logarithm of the indirect utility implies that the local planner's objective displays a preference for redistribution². Notice this functional choice implies, under uncertainty that the central planner also display risk aversion.

The first constraint is the balanced budget accounting equilibrium. This constraint applies to the most general case where the only requirement is that local government expenditures are fully offset by revenues³.

The second constraint is the production of the public good, which depends on the accumulated capital stock at the beginning of the period and the current expenditures for the period.

The third constraint describes the accumulation of municipal capital. It involves local investment but also a natural disaster shock $\epsilon_t^K, \in \{0, -L\}$, which affects the capital stock that will be available for the next period.

We assume that the probability of a natural disaster shock occurring is π , and that it is independent of the choices made by the agents. Finally, this shock occurs in period t after policy decisions have been set for this fiscal year, and we impose it is impossible to modify the financial decisions made before the shock at that point. This is in accordance with public policy rules in France as well as in many other decentralized countries (more information on local budgets' rules are provided in Section 2.2.2 below).

2.2.1 Municipal Planner's Problem

Subsidies and individual income being exogenous from the municipal planner's perspective, and only the sum of these two quantities appearing in the budget constraint, it is without loss of generality to consider that the municipal planner views

²If citizens were heterogenous, the objective of the planner would increase if we can directly transfer wealth from "rich" to "poor".

³Considerations of different institutional contexts with stricter conditions are discussed in Section 2.2.2.

R_t as a "gross" income incorporating subsidies. For all matters related to municipal planning, this perspective is adopted.

Explicit solution

As the local planner maximises the sum of logarithm of a Cobb-Douglas indirect utility, the general level of relative prices p_t , has no consequences on decisions leading to an interior equilibrium.

The first-order condition with respect to G_t provides:

$$(1 - \alpha)(R_t - \phi_t G_t - \theta_t I_t - (1 + r_{t-1})B_{t-1} + B_t) = \mu \phi_t G_t$$

Therefore,

$$\phi_t G_t = \frac{1 - \alpha}{1 - \alpha + \mu} (R_t - \theta_t I_t - (1 + r_{t-1})B_{t-1} + B_t)$$

Pluggin-in the optimal value of operating expenses into the planner's objective function, we derive the following objective:

$$E_0 \left[\sum_t \beta^t (\alpha \log(K_{t-1}) + (1 - \alpha + \mu) \log(R_t - \theta_t I_t - (1 + r_{t-1})B_{t-1} + B_t)) \right]$$

This leads to two first-order conditions with respect to I_t and B_t .

$$\frac{\beta\alpha(1-\pi)}{(1-\delta)K_{t-1}+I_t} + \frac{\beta\alpha\pi}{(1-\delta)K_{t-1}+I_t-L} = \frac{(1-\alpha+\mu)\theta_t}{R_t-\theta_t I_t-(1+r_{t-1})B_{t-1}+B_t} \quad (I_t)$$

$$\frac{1}{R_t-\theta_t I_t-(1+r_{t-1})B_{t-1}+B_t} = E_t \left[\frac{\beta(1+r_t)}{R_{t+1}-\theta_t I_{t+1}-(1+r_t)B_t+B_{t+1}} \right] \quad (B_t)$$

From (I_t) , we deduce

$$B_t = (1+r_{t-1})B_{t-1} + \frac{\theta_t(1-\alpha+\mu)}{\alpha\beta} \left(\frac{1-\pi}{(1-\delta)K_{t-1}+I_t} + \frac{\pi}{(1-\delta)K_{t-1}+\theta_t I_t-L} \right)^{-1} + \theta_t I_t - R_t$$

Thus, if the debt is stable $B_t = B_{t-1}$, the income R_t finances the financial charges $r_{t-1}B_{t-1}$, the investment, and a portion of the capital stock. Since this last part cannot be negative indefinitely, it sets a limit on long-term financial charges (and therefore on debt).

Let $\hat{I}_{\pi,L}(K, I)$ be the unique quantity positive, such that

$$\frac{1-\pi}{(1-\delta)K+I} + \frac{\pi}{(1-\delta)K+I-L} = \frac{1}{(1-\delta)K+\hat{I}(K, I)}$$

(without ambiguity, the dependence on parameters π, L will be omitted).

Given this function, we can write (B_t) as

$$\begin{aligned} \frac{1}{(1-\delta)K_{t-1} + \hat{I}(K_{t-1}, I_t)} &= E_t \left[\frac{\beta(1+r_t)}{(1-\delta)K_t + \hat{I}(K_t, I_{t+1})} \right] \\ &= \beta(1+r_t) E_t \left[\frac{1}{(1-\delta)K_t + \hat{I}(K_t, I_{t+1})} \right] \end{aligned}$$

Let $D_{t+1} = \beta^t \times \prod_{i=1}^t (1+r_i)$ be the discount factor, $X_t = \frac{1}{(1-\delta)K_{t-1} + \hat{I}(K_{t-1}, I_t)}$ et $X_t^* = D_t X_t$. The previous equation becomes

$$X_t^* = E_t[X_{t+1}^*].$$

The solutions are

$$X_{t+1}^* = X_t^* + \eta_{t+1}$$

where the process $(\eta_t)_{t>0}$ is a martingale difference (i.e., $E_t[\eta_{t+1}] = 0$).

In the absence of a bubble, this equation implies $X_t^* = X^*$. For any given value K_{t-1} of the installed capital at the beginning of the period, we deduce I_t as the unique solution of the equation

$$\hat{I}(K_{t-1}, I_t) = -(1-\delta)K_{t-1} + \frac{\prod_{i=1}^t \beta(1+r_i)}{X^*}$$

As $\hat{I}(K_{t-1}, I_t)$ increases with I_t , we observe that investment will grow (all else being equal) after a negative shock affecting the capital level. Noticing that the formula for B_t is, holding everything else constant, increasing with L , we also observe that, in the absence of any other modification, debt will increase after a shock, and this will be even more pronounced if the shock is strong.

The validity of the solution is analyzed in the appendix in section B.1.

Joint Dynamics of Observable Quantities

Here, we consider $r_{t-1}B_{t-1}$ the financial charges, the debt stock B_t (and thus r_t), the investment I_t , the operating expenses G_t , the representative income, subsidies (thus the gross income level R_t), and taxes T_t are observed at each date.

We observe that

$$\frac{R_t - \theta_t I_t - (1+r_{t-1})B_{t-1} + B_t}{\theta_t(1-\alpha+\mu)} = \frac{\prod_{i=1}^t \beta(1+r_i)}{X_0 \alpha \beta}$$

leads to

$$R_t - \theta_t I_t - (1+r_{t-1})B_{t-1} + B_t = (R_{t-1} - \theta_{t-1} I_{t-1} - (1+r_{t-2})B_{t-2} + B_{t-1})\beta(1+r_t)$$

and therefore we have

$$\phi_t G_t = \beta(1 + r_t)\phi_{t-1}G_{t-1}.$$

Current expenditures thus follow a dynamic that depends only on exogenous factors and the initial level of operating expenses. More precisely, the discounted nominal current expenditures are constant, as the previous equation can also be written as

$$\frac{\phi_t G_t}{\beta(1 + r_t)} = \phi_{t-1}G_{t-1}.$$

As for investment, it can be noted that (I_t) can also be expressed as

$$\frac{\beta\alpha(1 - \pi)}{(1 - \delta)K_{t-1} + I_t} + \frac{\beta\alpha\pi}{(1 - \delta)K_{t-1} + I_t - L} = \frac{(1 - \alpha)\theta_t}{\phi_t G_t}$$

This implies

$$(1 - \delta)K_{t-1} + \hat{I}(K_{t-1}, I_t) = \frac{\beta\alpha}{(1 - \alpha)\theta_t}\phi_t G_t$$

So, the investment I_t is the unique solution to this equation with a given level of installed capital.

The capital stock for the next period can then be deduced:

$$K_t = (1 - \delta)K_{t-1} + I_t + \epsilon_t$$

Using (I_t) , we derive the debt stock as:

$$B_t = \frac{1 - \alpha + \mu}{1 - \alpha}\phi_t G_t - R_t + \theta_t I_t + (1 + r_{t-1})B_{t-1}$$

Finally, the level of taxes can be deduced from the budget constraint

$$T_t = \phi_t G_t + (1 + r_{t-1})B_{t-1} - B_t + \theta_t I_t$$

Consequences of "Pure" Shocks

The model is simple enough to provide qualitative consequences of exogenous shocks. Throughout the following, we consider positive shocks, and variables not mentioned remain constant.

- Natural Disaster Shock

The capital at time t decreases. In the next period, investment increases. This additional investment is entirely financed by debt.

- Subsidy or Income Shock

The increase in subsidies at time t is entirely used to decrease the debt B_t .

- Interest Rate Shock

Budget expenditures increase, as well as investment, installed capital, and taxes.

- Relative Price of Public expenditures or Investment

If the relative prices of current expenditures and investments evolve proportionally, then so will the volumes. If, for instance, inflation is more important for ϕ_t than for θ_t , the volume of expenditure decreases compared to volume of investment.

Finally, note that even in the absence of a shock, it can also be observed that a municipality in which π and/or L are higher must invest more and has a higher debt stock.

2.2.2 Municipality constrained by debt

Local Budget Constraint: The French Case

Local authorities in France, i.e., local governments ranging from regions to municipalities, must adhere to five major budgetary principles. These rules aim to maintain the continuity of public services while preventing potential bankruptcies or mismanagement of the locality's finances (Gossin 2022).

The first principle is that of annuality, meaning that the budget must be voted on each year for one year. The second principle is the principle of unity, which requires that all expenses and revenues be recorded in a single document. The third principle is that of universality, ensuring transparency and traceability of public funds. The fourth principle is that of specialty, which requires public decision-makers to specifically allocate an expense to one or more specific services. The last principle is the principle of balance, stating that budgetary acts must be voted on in real balance and evaluated sincerely. It also specifies that loan repayments must be exclusively repaid by the municipality's own resources⁴.

⁴See articles L1612-1 to L1612-20 of the Code Général des Collectivités Territoriales for more details

Moreover, the use of loans for municipalities is regulated. The loan constitutes revenue for the investment section, implying that it is not possible to finance expenses other than investment. In no case should the loan be used to cover a deficit in the operating section or a lack of own resources to ensure debt amortization. Additionally, unforeseen expenses included in the investment section of the budget cannot be financed by the loan⁵.

On the other hand, financial costs, whether interest or related fees, are part of the expenses in the current account. As such, the financial costs must be offset by operating revenues, own resources, or tax revenues.

France is not the only country that requires its local governments to follow budgetary rules for the purpose of financial stability. These rules and restrictions on borrowing are even more common in federal or decentralized countries; however, they vary significantly among nations. According to a study by Vammalle & Bambalaite (2021) covering 29 countries, only three of them prohibit the use of borrowing to finance operating expenses, while nine have no restrictions. This seems to be the case in the United States as well, where although debt issuance or municipal bonds generally serve for investment and capital expenditures, local governments can (and do) also borrow to cover shortfalls and expenses (Ulbrich 2013).

In summary, the constraints on debt related to the French institutional context dictate that debt can only be used for investment expenses, and both the principal and associated financial costs can only be reimbursed by the municipality's own resources.

Modelling the constrained case

To examine the condition of borrowing constraint, we now consider the case of a municipality that is permanently constrained on debt. More precisely assume it must cope with a perpetual annuity to settle its arrears. Mathematically, the situation is clearly equivalent to a permanent loss of a subsidy of the same amount, with the debt stock maintained at zero⁶. This is the perspective we adopt now.

The first-order condition with respect to G_t becomes

$$\phi_t G_t = \frac{1 - \alpha}{1 - \alpha + \mu} (\underline{R}_t - \theta_t I_t)$$

where \underline{R}_t is the gross income reduced by the amount of the annuity. With only the investment left to determine, it satisfies the equation:

$$\frac{\beta\alpha(1 - \pi)}{(1 - \delta)K_{t-1} + I_t} + \frac{\beta\alpha\pi}{(1 - \delta)K_{t-1} + I_t - L} = \frac{(1 - \alpha + \mu)\theta_t}{\underline{R}_t - \theta_t I_t}$$

⁵Article L. 2322-1 of the Code Général des Collectivités Territoriales

⁶Note that this is likely to be incorrect from an accounting and legal perspective.

The tax is then worth:

$$T_t = \frac{(1 - \alpha)\underline{R}_t + \mu\theta_t I_t}{1 - \alpha + \mu}$$

Optimal response to shocks can be analyzed as in Section 2.2.1 above.

The response to a natural disaster shock then changes quite drastically compared to the unconstrained situation. Investment must increase to rebuild the capital, which, given fixed subsidies, leads to a decrease in current expenditures and an increase in taxes. The proportion of the two adjustments is entirely dictated by the ratio $\mu/(1 - \alpha)$. The higher this ratio, the more taxes increase, and the less current expenditures decrease. Furthermore, the comparative statics exercise on the parameters π and L is even more pronounced in this constrained case.

Therefore, we have modeled two opposing situations: on one hand, municipalities with the ability to incur debt, and on the other hand, municipalities without debt capacity. This allows us to observe the reactions to a shock of two types of municipalities in different financial situations. In the first case, when facing a natural disaster shock that destroys part of the municipality's capital, it will increase its investment to compensate for this loss. This investment will be entirely financed by debt, without an increase in taxes or a decrease in operating expenses. In the opposite case, the investment made during a natural disaster shock cannot be compensated by debt. Increasing taxes and decreasing expenses is rather inevitable.

2.3 Data

For the rest of the paper, we calibrate the model on the French municipal data. To create this panel database, which includes 36,806 municipalities between 2000 and 2019⁷, we use several sets from different institutions. The first set is the database of French municipal accounts available from the Ministry of Public Accounts.

The second part of the database consists of data on the characteristics of municipalities, demographic and socio-economic information is obtained from INSEE (National Institute of Statistics and Economic Studies).

Table 2.3.1 presents the descriptive statistics of the budget variables for French municipalities. The panel dataset allows us to gather a total of 725,839 observations, covering 36,806 municipalities from 2000 to 2019. Mergers and the creation of new municipalities implies the panel is unbalanced. This initial analysis reveals

⁷Although subsequent years are available in the data, we prefer not to use data affected by the COVID crisis as their reliability is questionable.

Table 2.3.1: Descriptive statistics of municipal accounts

	mean	sd	median	D1	D9
Unconstrained Case (municipalities: 8158)					
$\phi_t G_t$	675.35	216.53	635.87	447.02	949.96
$\theta_t I_t$	341.81	336.8	258.68	86.37	662.5
T_t	291.55	124.95	270.63	158.52	448.17
S_t	255.45	144.22	224.78	132.27	402.44
B_t	454.04	392.81	366.98	33.48	971.99
$r_t B_t$	18.88	17.56	14.72	1.28	40.83
R_t	18129.06	3904.93	18066	13209	22918
Constrained Case (municipalities: 2263)					
$\phi_t G_t$	986.74	792.93	802.68	531.76	1495.2
$\theta_t I_t$	613.13	817.42	409.76	158.68	1180.44
T_t	416.8	419.94	325.47	179.6	671.67
S_t	340.62	346.79	260.08	135.45	589.52
B_t	1070.58	1307.32	840.79	381.18	1805.83
$r_t B_t$	44.42	84.33	33.21	15.56	72.19
R_t	18279.07	4398.5	18028.51	13092	23447.47

Descriptive statistics of municipalities This table shows the descriptive statistics of the different municipal accounts. It is based on 2 samples of French municipalities between 2000 and 2019. These statistics are expressed in euro per capita. *Source* : Municipal accounts data are provided by the Ministry of Public Accounts and personal computations.

a significant heterogeneity among municipalities. We observe notable standard deviations, particularly regarding debt. This aligns with our intention to differentiate municipalities based on their debt capacity.

To further analyze the database, we begin by refining the panel. Indeed, municipal mergers are clearly not taken into account in our model. Keeping merged municipalities in our data would lead to artificial increase in population, expenditures, etc. In a similar vein, we exclude municipalities that experienced high demographic variability as those that have more than doubled their population over 20 years. Accordingly, extremely small and very large municipalities (Paris, Lyon, Marseille) have been excluded.

To investigate the two distinct dynamics outlined in the theoretical section, we use our panel data to differentiate between two groups of municipalities.

Unconstrained municipalities are those with minimal or no restrictions on their debt, allowing for significant fluctuations in debt levels between periods. Additionally, these municipalities are assumed to maintain solid financial health. As they can freely rely on debt, they can be characterized by notable variations of their debt levels. Second, our model predicts they should maintain relatively stable operating expenses over time. Indeed, the dynamic equation of $\phi_t G_t$ in the constrained case (in Section 2.2.1) indicates that operating expenses remain stable over time. Conversely, the constrained scenario involves municipalities with limitations on their debt, characterized by high and relatively stable debt levels over time.

To identify the two groups, we based our selection on three criteria for the constrained (and unconstrained) group: (i) municipalities with relatively stable (or unstable) operating expenditures over time, (ii) relatively low (or high) debt levels, and (iii) important (or minimal) variations in debt.

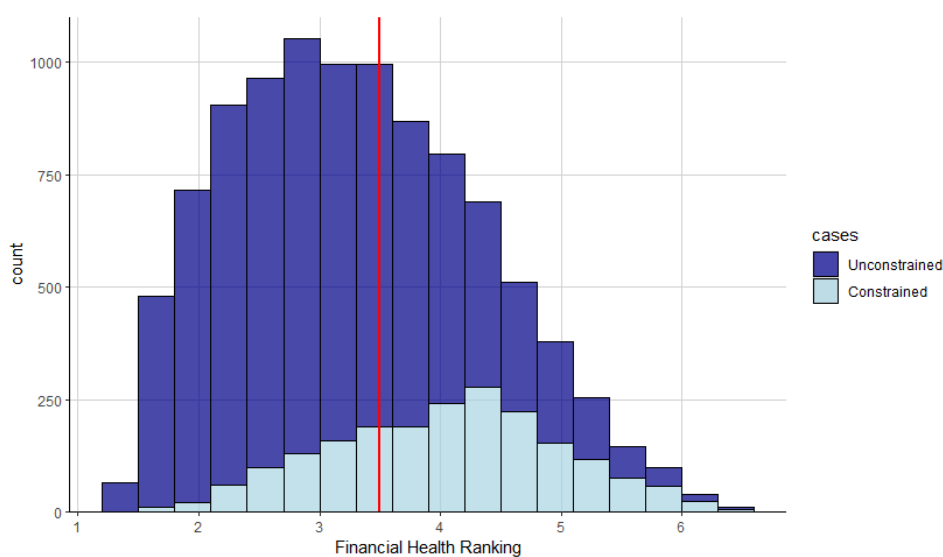
Unconstrained municipalities were selected based on their operating expenditure standard deviation being lower than the median standard deviation of the full sample. We also excluded municipalities experiencing significant spikes in expenditure from one year to another. Constrained municipalities are those with a debt per capita over 20 years higher than the total sample average and an average annual growth rate lower than the first quartile.

Descriptive statistics reveal that, on average, the standard deviation of current expenditures at the municipal level is only 71.1 for unconstrained municipalities, compared to 185.6 for constrained ones. Conversely, the average debt per capita for unconstrained municipalities is 450 euros, contrasting with 1200 euros per capita for the constrained group. Additionally, the standard deviation of debt per municipality is 370 for the constrained scenario, compared to only 190 for the unconstrained case (see Table B.1 in appendix).

Finally, we observed a financial health indicator developed by the Agence France Locale (hereafter AFL), a bank specialized in local governments financing solutions (Additional information on the financial health indicator in section B.2 of the Appendix). As this indicator is based on financial ratios that we already encountered in the theoretical part of the paper, we did not use it to perform our classification, but as a validation exercise. If our method to distinguish financially constrained municipalities from unconstrained ones is correct, we should observe a significant difference in the distribution of the indicator in the two sub-population.

Figure 2.3.1 shows that it is indeed the case: municipalities unconstrained by debt have a better average financial health rating than municipalities in the constrained group.

Figure 2.3.1: AFL ranking by group (Financial Health Indicator)



AFL ranking by group This figure shows the financial health ranking of the municipalities according to the Group breakdown. It is based on the two samples of 8158 French municipalities for the unconstrained case and 2263 municipalities for the constrained case between 2000 and 2019. *Source* : AFL - la banque des collectivités locales and personal computations.

2.4 Calibration

Both scenarios being identified, we now proceed with parameter calibration. As we consider municipalities, direct plug-in of calibrations used in macroeconomics would certainly be questionable, but we cannot rely on similar previous attempts either.

So we did our best to propose a calibration approach that can be readily applied to other database on local governments financial data, while providing realistic values in both scenarios.

Robustness checks can be conducted to assess the implication of choices presented below. These can partly rely on the individual variations we observe in our panel data.

Table 2.4.1: Parameters calibration and estimation

Parameter	Description	Value	
		Unconstrained	Constrained
r	Interest Rate	0.041	0.044
β	Actualization parameter	0.961	0.958
α	Capital Public Good Productivity	1/3	1/3
δ	Capital Depreciation Rate	0.2	0.2
μ	Relative Preference for the Private Good	17.6	12.4
π	Natural Hazard probability	0.31	0.22
L	Capital Loss (% of total capital stock)	7	7

Actualization parameter The parameter β represents the inter-temporal marginal rate of substitution of utility for the citizens from the planner's perspective. In the steady state, $\beta = \frac{1}{1+r}$. We use this relationship to calibrate this parameter using the estimated parameter r from the data, such as $r = \frac{\text{financial expenses}}{B}$.

Capital Depreciation rate The parameter δ represents the depreciation rate of capital over time. Given Article R.2321-1 of the Code Général des Collectivités Territoriales, depreciations constitute mandatory expenses for municipalities with 3,500 inhabitants or more. Eligible assets include movable property (furniture, vehicles, office equipment, etc.) and income-generating buildings. The duration of depreciation is defined according to an indicative scale such that the average time of an asset range from 5 to 10 years. This institutional rule allows us to calibrate the rate of capital depreciation within a range of 0.2 to 0.05. The upper range represents a municipality where all capital is subject to depreciation over 5 years, and the lower range where half of the municipality's capital is subject to depreciation over 10 years.

Productivity of Public Goods The parameter α represents the productivity of public goods relative to their factors of production: the municipality's capital K_t and operational expenses G_t .

The difficulty in calibrating α arises from lack any comparable examples. Considering the dearth of better alternatives, we then choose to stick to the usual practice

in macroeconomics setting α to 1/3.

As an indirect justification for this choice we can argue as follows. Gross wages of local employees ought to account for the largest part of operating expenses (at least in our French data case). If these gross wages do not display a systematic bias relative to private ones (for similar qualifications) the capital/labor ratio sharing should be roughly the same⁸.

Relative Preference for Private Goods The parameter μ represents the demand for public goods relative to private goods. In other words, the larger this parameter, the more utility depends on private goods. In the steady state of the unconstrained scenario:

$$R = \phi G \frac{1 - \alpha + \mu}{1 - \alpha} + \theta I + rB \Leftrightarrow R = \frac{\mu \phi G}{1 - \alpha} + T \Leftrightarrow \mu = (1 - \alpha) \frac{R - T}{\phi G}$$

The calibrated value of α , along with the data, allows us to calibrate μ using this equation.

For the constrained case, the calibration of the parameter μ is done as before, based on the steady state. Thus, we have:

$$\phi G = \frac{1 - \alpha}{1 - \alpha + \mu} (\underline{R} - \theta I) \Leftrightarrow \mu = \frac{(1 - \alpha)(\underline{R} - \theta I)}{\phi G} - (1 - \alpha)$$

where \underline{R} is the gross income reduced by the amount of the annuity, and I and G coming from the data.

The calibrations of μ in both scenarios reveal that the value of μ is higher in the unconstrained case than in the constrained case. This appears to be consistent with a sort of “revealed preferences” argument. In municipalities in which μ is lower, the provision of public goods should be larger. Now this could be financed by tax revenues, but, in practice, variations are low at the local level⁹. Hence lower μ should entail less financial capacities, leading to a higher probability to ultimately facing constrained financial decisions.

Natural Hazard probability The parameter π represents the hazard of a natural disaster occurring. It can be calibrated based on data regarding the incidence of shocks at the municipal level. The GASPARD 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 com-

⁸This argument is very partial since public capital is not privately owned. Hence, no capitalist revenue can be extracted.

⁹Arguing à la Tiebout also provide theoretical ground for this.

posed of the decrees of natural disasters since 1982. These data allow us to know exactly when a municipality was affected by a natural disaster and the type of disaster it is (flood, mudslide, land movement, drought, etc.). The parameter π correspond to inverse of the average duration between 2 shocks for a municipality, which is in average 3.25 years since 1982, of the unconstrained sample and 4.5 years for the constrained sample.

As we have not been able to find compelling explanations for this difference, we conduct robustness checks. These reveals that variation of π have very mior consequences on the results presented in the following Section.

Capital Loss from Natural Disasters The parameter L represents the loss resulting from a natural disaster. The calibration of this parameter is based on investment data. We assume that the loss results to the difference in investment variations between municipalities that experience a disaster and those that do not.

We observe annual investment variations of around 57% for municipalities that have not experienced a shock, compared to variations of 64% for municipalities that have undergone a shock in the post-disaster period, indicating a difference of 7%. We assume that this variation can be attributed to the natural disaster shock. The loss due to the shock would therefore be 7% of the initial capital.

2.5 Simulation

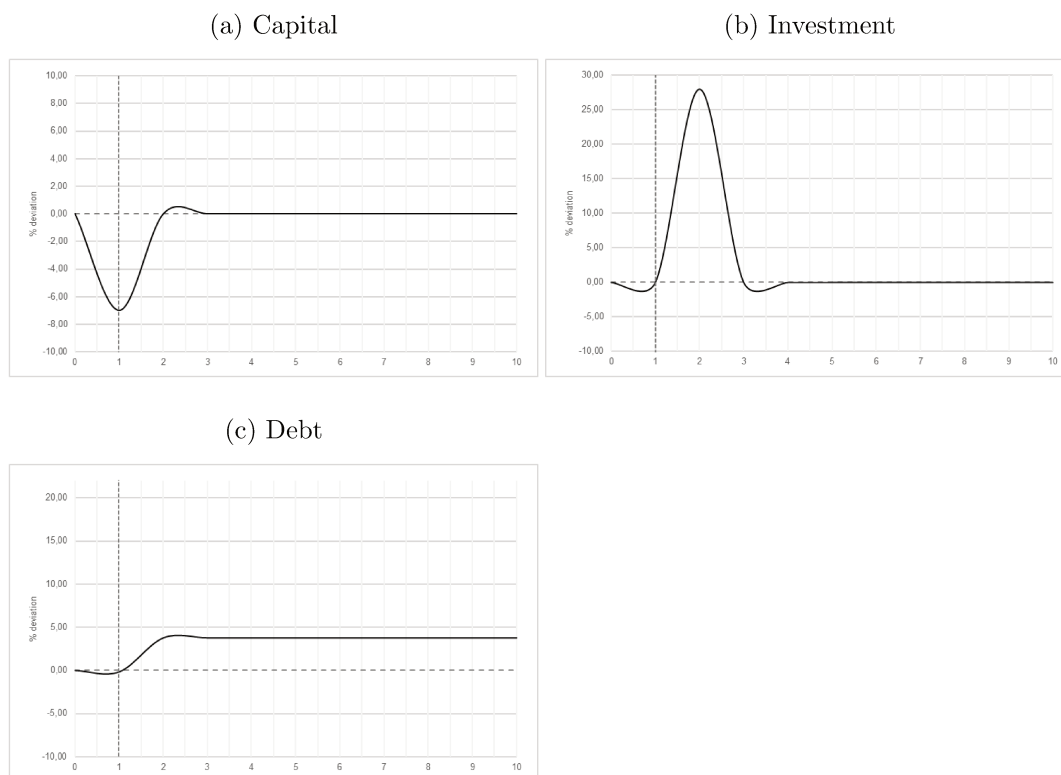
Figure 2.5.1 shows simulations of the unconstrained case for capital, investment, and debt following a natural disaster shock at the date. Graphs for other aggregates, such as current expenditures and tax revenues, are not depicted as these are not affected in this scenario.

Figure 2.5.1a shows the evolution of a unconstrained municipality's capital following a negative capital shock. We observe a decrease in the municipality's capital at the time of the shock, representing a 7% reduction from the municipality's capital at the steady state. However, we notice that this loss in capital is fully compensated in the subsequent period. Thus, the natural disaster has a direct impact on the municipality's capital, but the capital level returns to its initial level after one year¹⁰.

To compensate for this loss in capital, the municipality increases its level of investment. Figure 2.5.1b shows that the level of investment expenditures increases by 28% in period 2, i.e., the year following the shock, before returning to its steady state level. This indicates that the municipality increases its capital expenditures

¹⁰Notice that, contrary to the typical TFP shocks in RBC models, our natural disaster shock displays no autoregressive component. This largely explains why capital stocks quickly return to their original level.

Figure 2.5.1: Simulation unconstrained case



Notes: Simulation of the unconstrained case based on calibrated parameters and initial data provided by the Ministry of Public Accounts and the Ministry of the Environment. The x-axis is expressed in % deviation from the steady state, and the y-axis represents time in years.

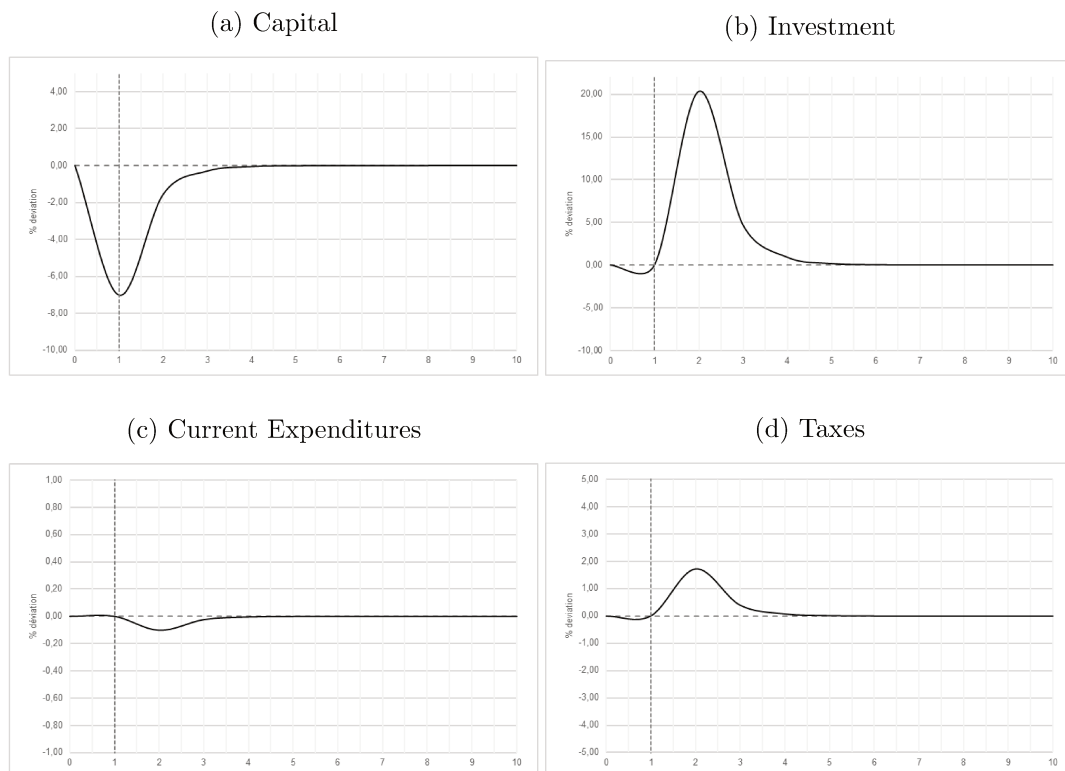
only once to fully compensate for the damage caused by the shock. We do not observe any persistence in the effects on investment expenditures. Similarly, we do not observe any effect on operating expenses, which remain stable and are not affected by the natural disaster.

As described by the model, in the unconstrained case, municipalities do not resort to tax hikes, they only resort to borrowing. Figure 2.5.1c shows that from period 2, the year following the shock, the debt stock increases by 3.8% compared to its initial level. We also notice that the debt stock stabilizes at this higher level. Following a natural disaster, municipalities increase their debt stock to offset the shock, and this effect on debt persists over time. Municipalities affected by a natural disaster maintain a higher level of debt. These municipalities have the possibility to maintain this higher level of debt stock at all periods. Furthermore, these municipalities have no incentive to return to the initial level of debt.

In this unconstrained case, municipalities experiencing a shock and therefore a loss of capital will restore their capital level in a single period. To compensate for this

loss, they will significantly increase their level of investment expenses, which they will finance by maintaining a higher level of debt. This scenario is only possible in cases where a municipality is not constrained by debt and therefore has the ability to borrow unlimitedly.

Figure 2.5.2: Simulation constrained case



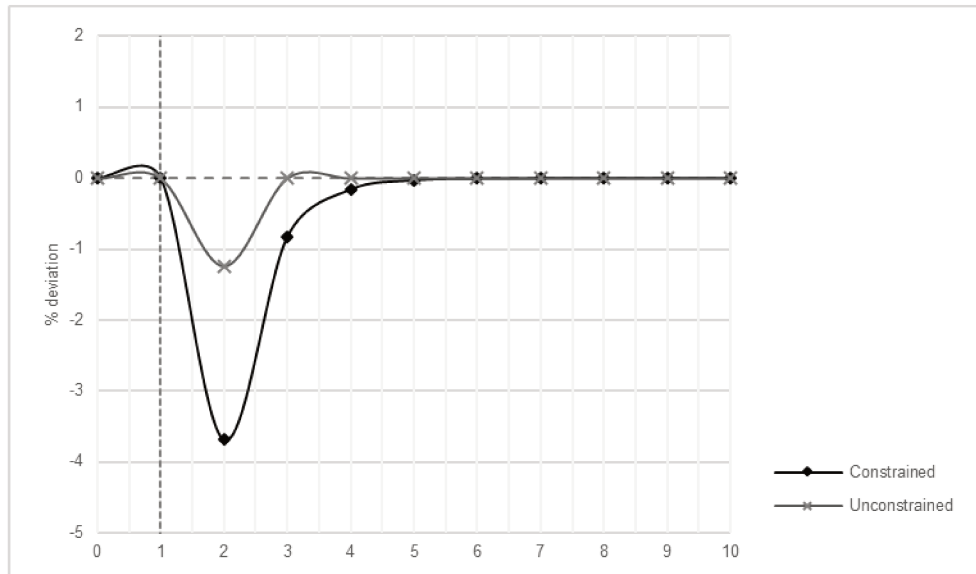
Notes: Simulation of the constrained case based on calibrated parameters and initial data provided by the Ministry of Public Accounts and the Ministry of the Environment. The y-axis is expressed in % deviation from the steady state, and the x-axis represents time in years.

Caveat: the scale of the y-axes varies across the graphs.

Figure 2.5.2 presents the evolution of municipalities' accounts in this constrained case.

Figure 2.5.2a depicts the evolution of the capital of a municipality affected by a disaster at period 1, thus showing a 7% decrease in capital at the time of the shock. However, we note that the initial capital level takes 5 periods to recover. Unlike the unconstrained case, the municipality requires several years to restore its initial capital.

To rebuild its capital, the municipality must increase its investment. However, symmetrically to the evolution of the capital stock, as shown in Figure 2.5.2b, investment expenditures primarily increase the year following the shock, by 20%, and then remain above the steady state for the following 5 years after the disaster.

Figure 2.5.3: Simulation of current welfare (V_t)

Notes: Simulation of the constrained and unconstrained cases based on calibrated parameters and initial data provided by the Ministry of Public Accounts and the Ministry of the Environment. The x-axis is expressed in % deviation from the steady state, and the y-axis represents time in years.

Finally, to finance this increase in capital expenditure, the municipality will use two different channels. Firstly, it will slightly decrease its operating expenses for 2 years after the disaster, by around 0.1% in the first year. At the same time, the municipality will increase its tax revenues for 5 years, by around 1.7% in the first year. This decrease in operating expenses will allow it to increase its revenues less than it would have had to.

We observe that municipalities unable to borrow will experience more persistent effects of the shock on their accounts. Indeed, whereas municipalities in the first scenario will take only one year to recover after the disaster, those in the second scenario will take 5 years to return to their initial state and will have to increase their tax revenues and decrease their operating expenses at the expense of the well-being of their constituents. On the other hand, municipalities not constrained by debt will increase it in the long term, which can have an impact on their financial health and push them towards the constrained scenario, especially considering the need for subsidies from higher levels of government to maintain this level of debt.

Figure 2.5.3 provides a more precise observation of the welfare of citizens in each scenario. This figure shows that following the shock, the welfare of individuals decreases due to the destruction of the municipality's capital. In the constrained scenario, we observe a decrease of only 1.25% due to this capital loss. In the second

scenario, we observe a larger decrease in well-being, 3.7%, and this decrease persists for 3 years. Indeed, the destruction of capital, as well as the decrease in operating expenses — both factors of production of public goods — lead to a decrease in utility. Furthermore, the increase in taxes over several periods and the municipality’s difficulty in rebuilding its entire capital also affect the welfare of citizens.

2.6 Conclusion

In this article, we examine municipalities’ responses to a natural disaster. Our perspective focuses on local governments, particularly municipalities, since they are the closest to citizens and are also directly affected by the degradation of their assets. Local authorities are indeed the primary holders of physical public assets, which they use to provide local public services. We model the natural disaster shock as a loss of part of the municipality’s capital stock, the same stock used to provide local public services to residents.

Our model shows that the degradation of this capital triggers an immediate response from municipalities to increase their investment expenditures to compensate for the loss. This result is consistent with empirical literature showing that municipalities increase their expenditures in the aftermath of a natural disaster (Morvan 2022, Masiero & Santarossa 2020, Miao, Hou, et al. 2018).

We show that the initial financial health of municipalities, as determined by their access to borrowing, is a significant factor in their financing decisions. Municipalities with unconstrained access to debt borrow to compensate for the loss while maintaining the same level of taxes and current expenditures. In contrast, municipalities without debt capacity will need to raise taxes and reduce operating expenses, to offset the increase in investment expenditures. However, in the case of municipalities not constrained by debt, they will maintain a higher level of debt in the long term. This could deteriorate their financial health. On the other hand, municipalities constrained by debt will experience the effects of the shock over several periods and significantly deteriorate the well-being of their citizens.

We investigate the relative size of the response to a natural disaster shocks by means of simulations, based on calibrations we partly derived from a French panel dataset. This dataset is divided in two parts that are meant to represent both the constrained and unconstrained cases.

Our approach to local governments financial choice, is, to the best of our knowledge, a novelty. Our objective was therefore to undertake a sound theoretical approach to the joint dynamic modeling of local budgets, that we seek to validate through calibration and simulation using French data.

In absence of relevant comparative piece of literature, the model we propose arguably remains a first attempt, many aspects of which are still rather “mechanical”. But we envisage several extensions are worth mentioning. We shall now briefly present some, together with the challenges they raise.

First, allowing the municipality to experience periodic constraints on borrowing would certainly be more relevant than the two “polar” cases we discuss. Beside computational burden of models with occasionally binding constraints, (in particular for a rather short time dimension imposed by yearly panel dataset) a difficult problem is to derive the mechanism triggering ability to rely on debt. Indeed, municipalities (at least in the French case) cannot rely on collateral to issue debt. To study the supervision of access to debt for municipalities, the political dimension can hardly be ignored.¹¹.

Second, the time dimension of our panel data allows in principle to provide empirical equivalent to the dynamic patterns we derive, following a PVAR-type approach. However, the main problem is the availability of data. Local government do not provide quarterly but yearly data. The current sample size (despite being the longest we can rely on) appears rather small for such an exercise. Moreover for the exercise conducted in this paper we take advantage of an extra source of information to identify specific, local shocks. Doing so for other (in particular political) ones, looks like tremendous task.

A final possibility would be provide other agents with decisions’ powers. For instance, citizens could choose to leave if the level of utility is too low in their actual municipality. This would entail endogenous demographic reactions to shocks, affecting the denominator of per capita variables. In a similar vein, access to debt/saving can partly be provided by banks, leading to endogenous interest rate levels. Finally, the amount of grants could result from a bargaining game between local and global governments.

¹¹In the French case, the prefect (responsible for the administration of the department) must give approval in the case of significant borrowing requests

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B Appendix

B.1 Solution validity

We must now verify that for the selected solution, the quantities allowing the computation of the planner's objective exist. First, recall that as soon as $\pi < 1$, we have $\hat{I}(K_{t-1}, I_t) > I_t - L$, thus the equation

$$\hat{I}(K_{t-1}, I_t) = -(1 - \delta)K_{t-1} + \frac{\prod_{i=1}^t \beta(1 + r_i)}{X^*}$$

implies that $K_t = (1 - \delta)K_{t-1} + I_t + \epsilon_t^K$ is positive even in the event of a natural disaster as long as $1 + r_i > 1$, an assumption that we will retain hereafter.

Given (I_t) , this also implies that $R_t - I_t - (1 + r_{t-1})B_{t-1} + B_t$ is strictly positive. Therefore, the objective is always defined.

To demonstrate that the objective is bounded, it suffices, to show that it is bounded when $\pi = 0$. In this case, $\hat{I}(K_{t-1}, I_t) = I_t$ and the selected solution implies

$$K_t = \frac{\prod_{i=1}^t \beta(1 + r_i)}{X^*}$$

and

$$\frac{R_t - \theta_t I_t - (1 + r_{t-1})B_{t-1} + B_t}{\theta_t(1 - \alpha + \mu)} = \frac{K_t}{\alpha\beta}$$

We have to do is show that the series

$$\sum_i \beta^i \log(K_i)$$

exists, which is the case, for example, if the level of rates r_t is uniformly upper bounded, the assumption we'll retain hereafter¹².

B.2 Creation of constrained and unconstrained groups from data

The financial health rating established by the Agence France Locale (AFL). The Agence France Locale is a bank specialized in public authorities and local government financing, thus they create an indicator of the financial health of municipalities. This AFL rating serves as an indicator of the sound budgetary functioning of local authorities. It is calculated based on various indicators such as debt, self-financing capacity, and savings. This rating provides us with a variable signaling the average financial health level of each municipality, ranging from 1 to 7, where

¹²It should be noted that this second assumption is not entirely trivial. It essentially assumes that the municipality always has access to borrowing. A complete prohibition of borrowing would, in fact, imply in our model that the interest rate is infinite.

Table B.1: Descriptive statistics for constrained and unconstrained groups, aggregated at the municipal level

	Unconstrained	Constrained
Expenditures		
mean	675.4	986.8
sd	71.11	187.1
Debt		
mean	454.0	1070.5
sd	192.8	419.21
Financial health indicator		
mean	3.181	3.967
sd	1.059	1.174

Descriptive statistics of municipalities This table shows the descriptive statistics of the different municipal accounts. It is based on the two samples of 8158 French municipalities for the unconstrained case and 2263 municipalities for the constrained case between 2000 and 2019. These statistics are expressed in euro per capita, for the municipal accounts. The data are aggregated at municipal level, i.e. the mean represents the average of the mean of the variable at municipal level over 20 periods, and the standard deviation is in fact the average of the standard deviations of each municipality over 20 years for each group. *Source* : Municipal accounts data are provided by the Ministry of Public Accounts.

1 indicates municipalities in very good financial health and 7 those in a precarious situation. We consider that municipalities with an average rating between 1 and 2.5 have "very good" financial health. Then, municipalities with a rating higher than 2.5 and lower than 3.5 have good financial health, and municipalities with a rating higher than 3.5 have an average or poor financial health. This indicator does not allow us to create the initial groups, which are made from the data of the municipalities' accounts, mainly the data of operating expenses and debt. However, we use this indicator as a verification of our correct distribution of municipalities in the groups. We observe in the graph 2.3.1 that the municipalities in the constrained case have, on average, a worse financial health than the municipalities in the unconstrained case. However, this is a rough measure since the graph represents the average over 20 years of the financial health rating of a municipality, and this rating can vary greatly within this interval.

Chapter 3

Natural disasters and voter gratitude: What is the role of prevention policies?

This paper was co-authored with Sonia Paty* and published as Morvan, C. & Paty, S. (2024). Natural Disasters and Voter Gratitude: What Is the Role of Prevention Policies?. *Public Choice*.

Abstract

Natural disasters and related prevention policies can affect voter decisions. In this study, we analyze how the occurrence of natural disasters changes voter behavior in municipal elections and how prevention policies can mitigate the impact of such catastrophic events on budget accounts and might potentially be rewarded by citizens in upcoming elections. We exploit original data on French municipalities where incumbents sought re-election between 2008 and 2020. To estimate the probability of re-election at the municipal level in the event of a natural disaster we apply a Heckman model based strategy to avoid selection bias. We find that the occurrence of a natural disaster significantly decreases the chances of re-election of incumbent mayors. However, although we show that natural hazard prevention plans can mitigate the impact of catastrophic events on budget accounts, they are not rewarded by citizens in upcoming elections. The myopia hypothesis is confirmed by our findings: voters reward incumbents for delivering investment spending or decreasing debt but not for investing in disaster preparedness.

*Professor of Economics, Université Lyon 2, GATE Lyon Saint-Étienne

3.1 Introduction

Since the 1960s, there has been a tenfold increase in the number of natural disasters across the world (EM-DAT, CRED).² The academic literature shows that climatic events influence voters' perceptions of incumbents in different ways (see contrasting results in e.g. Bechtel & Hainmueller 2011, Ashworth et al. 2018, Gallego 2018, Klomp 2020, Masiero & Santarossa 2021).

On the one hand, a large stream of research shows that following a natural disaster citizens punish incumbents at elections (Bovan et al. 2018). Using US data, Achen & Bartels (2012) found that in the 1896-2000 period flood events had a negative effect on electoral support for the incumbent president's party. They explain this effect as the result of egotropic retrospective voting or "blind retrospection", meaning that if voters suffer, incumbents pay at the poll regardless of whether or not they are responsible for the suffering caused. The authors argue that natural disasters can result in resource scarcity which leads to unequal distribution of resources, and therefore low satisfaction with the incumbent. This finding has implications for democratic accountability since it "significantly degrades the efficacy of elections as mechanisms for inducing incumbent leaders to pursue their citizens' subjective well-being" (Achen & Bartels 2016, p. 23).

However, another stream of work shows that in some cases the occurrence of a natural disaster and the relief efforts implemented can be exploited in upcoming elections (Masiero & Santarossa 2021). The term "attentive retrospection" refer to when voters include the elected official's relief efforts in their assessment of the candidate. Efforts to mitigate the effects of a natural disaster and respond to external shocks to the economy to the benefit of local consumers and business can act as an incentive for the voter to support the incumbent officials. Also, in developing countries, natural disasters can generate in-flows of resources in the form of aid which increases the money available to buy votes. In Columbia, Gallego (2018) found that shock events can favor incumbents and that disasters were linked to leader survival through clientelism.

Although there is a large literature that investigates the impact of natural disasters on electoral outcomes, the specific impact of related prevention policies has received less attention. In the context of the United States, Healy & Malhotra (2009) show that voters rewarded the incumbent presidential party for delivering disaster relief spending but not for spending on disaster preparedness. These inconsistencies distort the incentives of public officials, leading governments to under-invest in disaster preparedness, thereby causing substantial public welfare losses.

However, natural disasters should increase the salience of prevention policies for

²<https://ourworldindata.org/grapher/number-of-natural-disaster-events>

voters. Although adopting a prevention plan is binding for many reasons (budgetary costs of implementing the plan, new building rules for citizens/voters etc.), it is widely accepted that construction methods and building technologies robust to flooding and to seismic events dramatically reduce the level of damage if there is a natural disaster (see e.g. Proverbs & Lamond 2017).

In this paper, we address the impact of catastrophic events on municipal electoral outcomes controlling for preparedness spending in the form of natural hazard prevention plans. We combine original data from a municipal level French natural disasters and prevention policies dataset with data on local public spending and municipal electoral results in the period 2008 to 2020.

We start by addressing the effect of natural disaster prevention on budget accounts following a shock. The empirical literature on natural hazard prevention shows that ex-ante strategies are effectively mitigating damage to households in terms of housing, poverty, and agriculture (Skoufias 2003). However, while some research shows that natural disasters have long-term effects on local government budgets (Morvan 2022, Masiero & Santarossa 2020), few empirical studies examine the effect of prevention policies on municipal accounts.

We are interested in whether ex-ante disaster prevention policies have an impact on municipalities' short-term and long-term budgetary decisions, and whether citizens reward incumbents who implement such policies. Using a Heckman model to resolve sample selection bias, we analyze how the re-election probability of incumbent mayors in local elections differs between affected and unaffected municipalities controlling for prevention policies.

Our estimation results show that natural disasters have a negative effect on the re-election of incumbents. However, although we show that natural hazard prevention plans significantly and permanently mitigate the impact of catastrophic events on budget accounts, citizens do not reward prevention policies in upcoming elections. We corroborate the myopia hypothesis Sobel & Leeson (2006): voters reward incumbents for delivering investment spending or decreasing debt in the years before the election year but not for investing in disaster preparedness. Therefore, we confirm the long-term effectiveness of prevention policies for municipalities faced with natural disasters but show the ineffectiveness of elections as a mechanism to induce incumbent leaders to implement efficient natural disaster prevention plans.

Our paper adds to our understanding of how democratic institutions are influenced by disasters. Leeson & Sobel (2008) show that disaster-relief windfalls in the form of Federal Emergency Management Agency (FEMA) aid may increase corruption by increasing the benefit of fraudulent appropriation. Leeson & Sobel (2011) found that the bundled nature of political goods prevented voter-discipline mechanism from removing ineffective politicians from office following Hurricane Katrina.

Also, using FEMA disaster expenditure data for 1991 to 1999, Garrett & Sobel (2003) provide evidence that states that were politically important to the president had higher rates of disaster declaration. The remainder of this paper is structured as follows. Section 2 provides an overview of the institutional context in France. Section 3 describes the data and section 4 discusses our identification strategy. Sections 5 and 6 present the estimation results. Section 7 concludes the paper.

3.2 Institutional context

3.2.1 Municipal elections in France

Municipal elections in France allow citizens to elect the city's mayor who chairs the city's council, and to elect the councilors. The usual term of office is six years; the last four municipal elections were held in 2001, 2008, 2014, and 2020.

The election process depends on the size of the municipality. Since a law reform introduced in 2013 which applied to the 2014 municipal council elections, the process can take two forms. In municipalities with less than 1,000 inhabitants, the election of municipal councilors involves two voting rounds and is based on majority votes. In the first round, candidates are elected if they receive an absolute majority of the votes cast and a quorum of a quarter of the registered voters. In the second round, election is based on a simple majority. In municipalities with more than 1,000 inhabitants election depends on a proportional representation system with a majority premium. The election of councilors involves two rounds and a list system (of candidates) with proportional representation. Note that prior to the 2013 reform, the proportional list system applied only to municipalities with more than 3,500 inhabitants. In most cases, voting is by municipality; the exceptions are Paris, Lyon and Marseille (PLM) where voting is by district ("arrondissement").

A particularity of France is that its approximately 35,000 municipalities include over 70% with fewer than 1,000 inhabitants. The municipalities are responsible for local roads, schools, sports and cultural facilities, parks and gardens, sewage system maintenance, and waste treatment.

Mayors are responsible for the safety of the local population, and preparation for and organization of rescue activities in the event of a crisis. In the absence of appropriate prevention policies incumbents are responsible for any damage caused by a natural catastrophe.³

³The mayor of La Faute-sur-Mer in France received a 2 year prison sentence for manslaughter following storm Xynthia which resulted in the deaths of 29 inhabitants.

3.2.2 Natural disasters

In France, natural disasters refer to a particular type of climatic event. In some specific cases, a major meteorological event can be cataloged as a natural disaster. Natural disaster status applies to exceptional, high intensity, and non-standard meteorological events such as floods, mudflows, droughts, land movements, earthquakes, storms, etc.⁴

The designation of "natural disaster" is decided by ministerial decree following consideration of the arguments proposed by the mayor of the municipality suffering the damage. Although central government makes the final decision, the municipality mayor is responsible for requesting the natural disaster classification and providing supporting official information and independent expert technical reports detailing the level of physical destruction. Citizens are aware of the key role of the mayor in the classification of a natural disaster since this depends on the information provided by the municipality to the central government. The designation of natural disaster gives citizens the right to apply for compensation; this is fundamental since most insurance policies exclude damage caused by extreme weather events. In the case that central government rejects the request for an event to be classed as a natural disaster, this is likely to be seen as a failure on the part of the mayor.

The role of the municipality is important during and after a catastrophic event; the mayor is responsible for safety and crisis management, and for organizing protection of and support for the population. Managing a natural disaster can generate additional costs which must be borne by the municipality and may be related to provision of emergency services including transportation, emergency accommodation, and communication, for example.

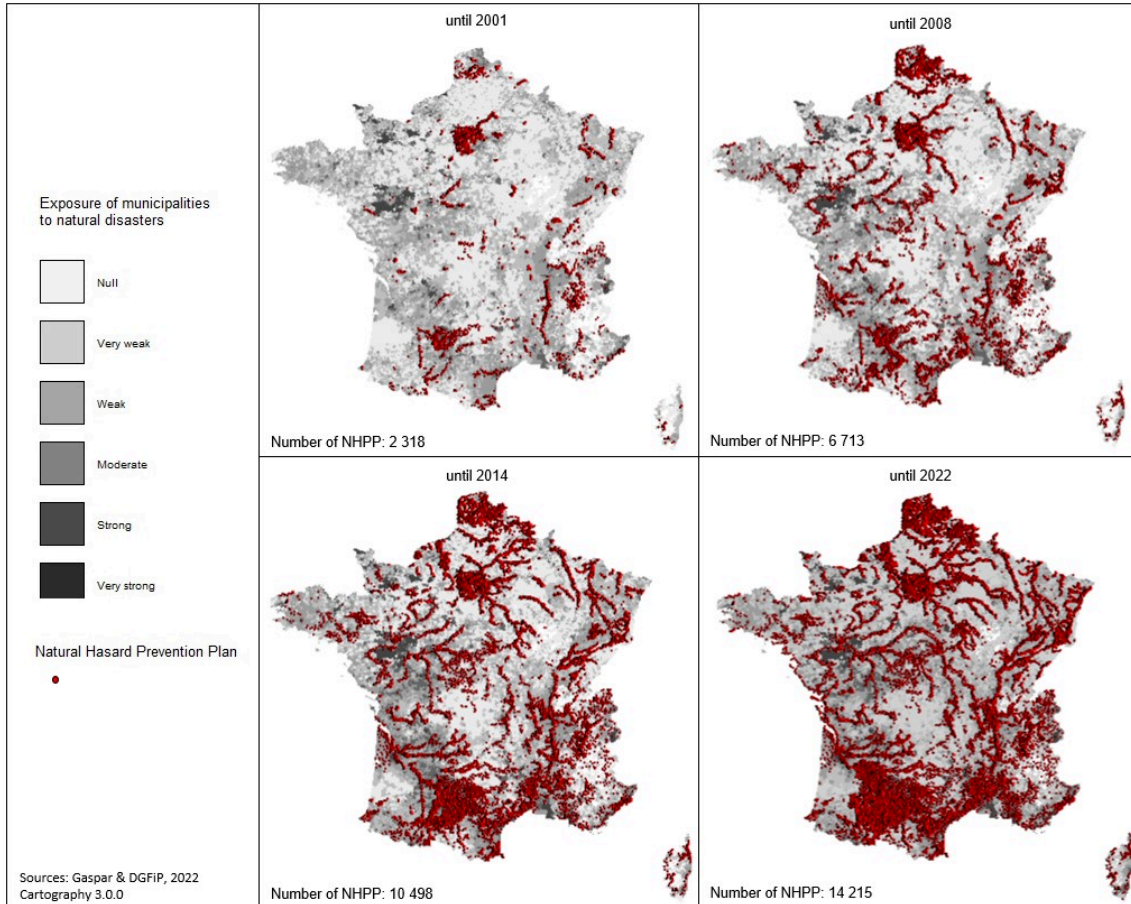
3.2.3 Natural hazard prevention policies

In France, the "Plan de Prévention des Risques Naturels" or natural hazard prevention plan (NHPP) is designed to prevent or avert the damage caused by a natural disaster (see Morvan 2022). The NHPP defines the rules related to public networks and infrastructures to facilitate evacuation measures and emergency interventions. It defines the procedures enabling maintenance of public spaces, and acquisition, management, and maintenance of works and equipment, including, for example, watercourse development work to prevent flooding.

Thus, the NHPP is an important part of a prevention strategy aimed at distinguishing zones either directly exposed to risk or not exposed to direct risk but

⁴According to article 1 of the July 13, 1982 law, "the effects of natural disasters should be regarded as direct non-insurable material damage caused by the abnormal intensity of a natural agent as its determining cause, where the usual measures to be taken to avoid such damage could not prevent its occurrence or could not be taken". Source: Ministry of the Interior.

Figure 3.2.1: Distribution of natural disasters and prevention plans since 1982



Notes: Distribution of natural disasters and prevention plans since 1982. This map shows the total number of approved Natural Hazard Prevention Plan and of natural disaster at the municipal level. This map considers all the natural hazard prevention plans that have been approved since 1982. The dates chosen for the graphic representations are those of the municipal elections. *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 (Direction Générale des Finances Publiques).

related to occupations or uses that might aggravate ongoing risks. For instance, the NHHP regulates land uses in areas exposed to risk.

The NHPP is a national plan which is centrally managed by the "préfet" who is a representative of the State. Local authority implementation of the NHPP is mandatory, and prevention, protection, and safeguarding measures in the zones defined by the NHPP are the responsibility of the local authority (as part of its general responsibilities) and private individuals. Implementation of the measures defined in the NHPP generates a cost to the municipality. These measures include

provision of information about natural risks, construction prohibitions, technical requirements related to residential buildings and other specific infrastructures, and investment in risk protection. Municipalities with an NHPP in place can apply for funding from the State *Barnier* fund (set up to prevent major natural disasters) to cover (up to 50%) of the expenditure related to risk prevention requirements. In extreme cases, the *Barnier* fund provides compensation for the expropriation of property exposed to major risks.

Figure 3.2.1 shows the distribution of the NHPP across the French territory between each electoral period. Since 2001, adoption of the NHPP has increased considerably; in 2022, a third of all municipalities had a protection plan in place, 88% having opted for an NHPP following experience of a natural disaster. However, 60% of all municipalities that have suffered a natural disaster have not implemented an NHPP. Most of these municipalities have experienced only a small number of shocks.

Figure 3.2.1 shows that as the number of shocks increases, the proportion of municipalities with no NHPP decreases, i.e. the proportion of municipalities with a prevention strategy in place increases with the number of shocks experienced.

Finally, we would emphasize that although the requirements set out in the NHPP are the responsibility of the municipality, since 2017, several municipalities merged to become inter-municipal communities⁵ which allows the imposition of a tax (GEMAPI or "gestion des milieux aquatiques et prévention des inondations") to finance implementation of the NHPP.

Before 2018, the involvement of inter-municipal level in environmental policy was minimal and implementation of an environmental policy was compulsory only for 2% of all municipalities which included the biggest communities (urban communities and "metropoles").

3.3 Data

To investigate the impact of a natural disaster on electoral outcomes, we combine data from the data sets provided by several different institutions.

Data on natural disasters since 1982 and information related to the NHPP are from the GASPARE (Gestion Assistée des Procédures Administratives relatives aux Risques) or assisted management of risk administrative procedures database, made available by the Ecology Ministry. They provide information on when a municipality was affected by a natural disaster (as defined in subsection 2.2) including date and

⁵Inter-municipal communities are unions of several municipalities to enable collective financing and management of some local public services. Currently, all French municipalities are grouped within larger jurisdictions (known as 'Etablissements Publics de Coopération Intercommunale' or EPCI in French).

type of shock (drought, flood, seismic event, etc.) but provide no details on the intensity of the natural disaster or the damage caused. GASPAR data also includes information on NHPPs including date of adoption, expertise involved, and types of risk considered.

Data on municipal electoral outcomes are from the Ministry of the Interior and provide demographic (age, gender) information for mayors. They include 90,083 observations between 2008 and 2020 of incumbent mayors running for re-election, 58,535 of whom were re-elected. We created two dummy variables for application to the office of mayor, and re-election of the incumbent mayor.

We also collected Ministry of the Interior data on the political leaning of elected mayors in the list-based electoral system. We defined six categories far left, left, center, right, far right, other. We consulted information on presidential election results to approximate the municipality's political alignment with central government.

Finally, to control for electoral competition, we included a variable for "closeness" which measures the difference in vote shares between the list of those with the highest scores and the list of the second highest scores in the first round of the election (**cox**). The political data were collected from the Ministry of the Interior.

We also exploited other sources of data. INSEE (the French national statistic institute) was our source of population data (municipal population and share of people over 65), municipal unemployment rate, and median income, and information on several variables related to municipality budget decisions are from the Ministry of Public Accounts (DGFIP) French municipal accounts database.

To take account of possible merger of a municipality into an inter-municipal union which reduces the power of the municipality mayor, we used information on inter-municipal cooperation provided by the Ministry of the Interior. We created a categorical variable that includes three categories: isolated municipalities i.e. those that do not belong to a group of municipalities, communities of municipalities i.e. a type of cooperation where municipalities are not closely integrated, and groups of integrated municipalities which include metropolitan areas ("métropoles"), urban communities and agglomeration communities. The reference category is communities of municipalities. As already mentioned, since 2017 the number of inter-municipal communities has increased allowing implementation of an NHPP using the GEMAPI tax. We can control for the existence of a community but do not have information on possible implementation of an NHPP by inter-municipal unions.

Appendix table C.1 presents the descriptive statistics.

3.4 Methodology

3.4.1 The causal impact of natural disasters on municipal budgets

First, we observe the causal impact of the occurrence of a natural disaster on municipal budgets. Our panel data on municipal budgets (2000-2020) and information on natural disasters allow us to conduct (i) an event study employing a difference-in-differences (DiD) and multiple time periods methodology *à la* Callaway & Sant’Anna (2021), (ii) and a triple difference methodology (Olden & Møen 2022).

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

$$Y = \alpha_1^{s,t} + \alpha_2^{s,t} Shock_s + \alpha_3^{s,t} \mathbf{1}\{T = t\} + \beta^{s,t} (Shock_s \times \mathbf{1}\{T = t\}) + \gamma \mathbf{X} + \varepsilon^{s,t} \quad (3.1)$$

The outcome variable Y is one municipality’s account per capita that could be expenditures, revenues, or grants.⁶ The variable $Shock$ is the natural disaster and is equal to 1 if the municipality i was first treated in period s , i.e. $Shock_{i,s} = \mathbf{1}\{Shock_i = s\}$.

We also consider a vector for municipal characteristics \mathbf{X} which includes several time-varying financial, socio-demographic, and socio-economic covariates. Specifically, these are the logarithms of the municipality’s debt and tax revenue. The socio-demographic variables are population size, share of people aged under 20 years, and share of people aged over 65 years.

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

To identify the role of a prevention strategy, we split the municipalities into two sub-samples based on their prevention strategy status. One sub-sample includes municipalities with a prevention plan in place prior to the natural disaster, the other includes municipalities with no prevention strategy in place before the shock.

⁶We use the inverse hyperbolic sine transformation the inverse hyperbolic sine transformation which allows minimum loss of data during the transformation.

The former sub-sample includes only 5,522 compared to 28,871 in the latter sub-sample. Our strategy allows us to evaluate the effects of a natural disaster on the budgets of municipalities that had a prevention plan in place, and those with no plan in place which did not anticipate a disaster or its consequences.

However, our method has the limitation that it forces us to split our sample into these two sub-samples which means we cannot identify the additional effect of an NHPP in a municipality that suffered a natural disaster after the disaster has occurred. By applying a triple-difference methodology we can identify the interaction between these elements:

$$Y_{i,t} = \beta_1 Treated + \beta_2 Post + \beta_3 NHPP + \beta_4 Treated \times Post + \beta_5 Treated \times NHPP + \beta_6 Post \times NHPP + \beta_7 Treated \times Post \times NHPP + \gamma_i + \delta_t + \mathbf{X}_{i,t} + \varepsilon_{i,t} \quad (3.2)$$

Treated is equal to 1 if the municipality has never experienced a natural disaster. *Post* is equal to 1 for the period after a natural disaster in a municipality. *NHPP* is equal to 1 if the municipality had an NHPP in place before the disaster (from the year the municipality started the NHPP process). We also include time and individual fixed effects. \mathbf{X} is a vector for municipal characteristics, which includes several time-varying financial, socio-demographic and economic covariates.

However, Strezhnev (2023) advises caution when implementing these estimators in a staggered case. Differences in the timing of treatment related to both a natural disaster and implementation of an NHPP, are likely to introduce bias in the triple difference estimation. We also estimate the impact of a natural disaster on the municipal budget using the more conventional two-way fixed effects method.

3.4.2 The causal impact of natural disasters on electoral outcomes

To identify the causal impact of natural disasters on electoral outcomes, we employ a strategy based on a Heckman model. This type of model avoids problems related to selection bias. Before we can investigate whether or not an incumbent mayor will be re-elected, we need to know more about the candidate. The decision of the mayor to run for re-election is likely to be influenced by several factors that will influence the chances of re-election. For example, experiencing a natural disaster event while in office is likely to influence the mayor's decision to continue in politics. To estimate this, we use a Heckman model with two dummy variables where the selection equation considers the incumbent's candidacy and the outcome equation considers the incumbent's re-election.

The selection equation estimates the effect of the covariates on the candidacy of the incumbent mayor, *candidate_i* is a dichotomous variable which takes the value 1

3.5. Effect of natural disaster on budget outcomes according to implementation of a prevention plan

if the mayor in municipality i is seeking re-election and 0 otherwise.

$$Candidate_i = Shock_i\tau_1 + NHPP_i\delta_1 + X_i\beta + \mu_i \quad (3.3)$$

The outcome equation considers only incumbents standing for re-election. It allows us to estimate the effect on the dichotomous variable $Reelected_i$ which takes the value 1 if the mayor i is re-elected.

$$Reelected_i = Shock_i\tau_2 + NHPP_i\delta_2 + X_i\gamma + \nu_i \quad (3.4)$$

In both stages of the model, the variables of interest are $Shock_i$ and $NHPP_i$. The first is a dummy variable which equals 1 if a natural disaster occurred during the mayor's term of office in municipality i . The second is a dummy variable for an NHPP and equals 1 if the mayor in municipality i implemented an NHPP while in office. We also consider a vector of the control variables X_i , which includes several budgetary, political, individual, and municipal covariates. We use the mayor's individual characteristics such as age and gender and municipality characteristics such as population, median income, and inter-municipal cooperation. We also include budgetary variables for capital expenditure and debt.

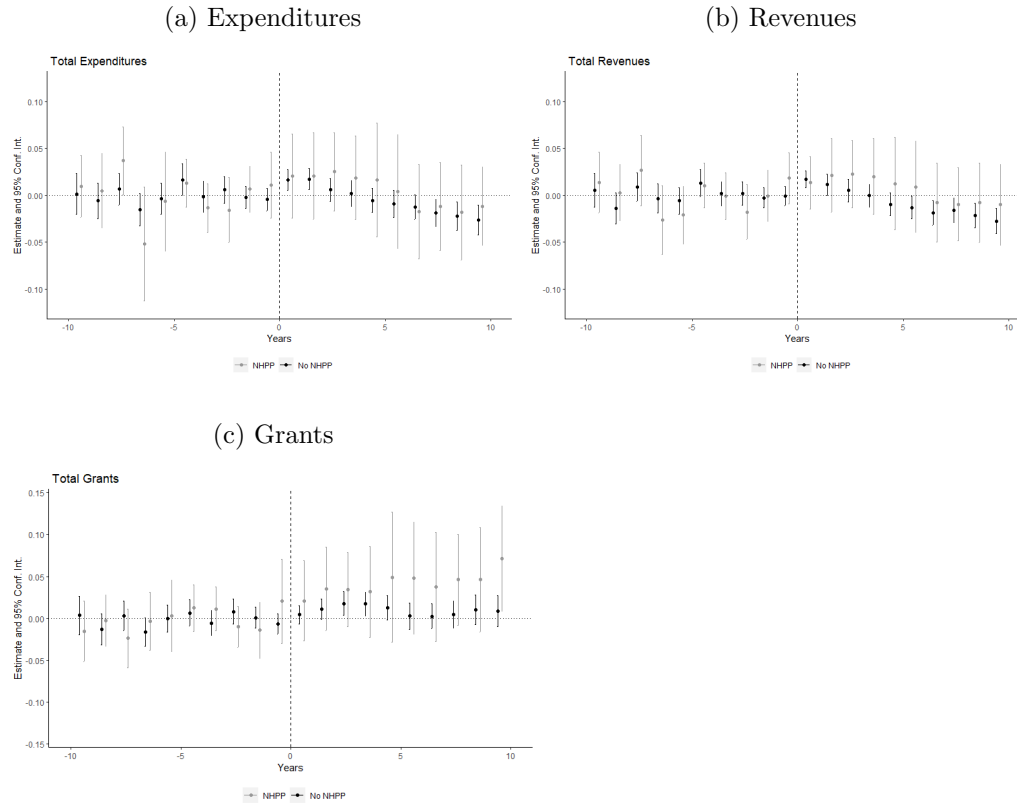
Finally, to enable identification (Wooldridge 2010), we include only two additional variables: age squared and the number of candidates. Age squared allows more accurate modeling of the effect of age which may have a non-linear relationship with being a candidate. We include the number of competitors since this might influence the mayor's choice to run for election again. Each election is estimated separately and via pooled estimation with a temporal fixed effect for the 2014 election - the year that the electoral system changed in relation to municipalities with between 3,500 and 1,000 inhabitants.

3.5 Effect of natural disaster on budget outcomes according to implementation of a prevention plan

Here, we investigate the role of inclusion of a prevention strategy in the municipal budget accounts to respond to a natural disaster (droughts, floods, seismic events, etc.) during our period of study (2000-2020).

As discussed in section 3.2.3, the NHPPs are aimed at encouraging local jurisdictions to invest in risk prevention. They allow the municipality to obtain funding to treat territories subject to risks and to provide information to their inhabitants. We assume that municipalities with an NHPP in place are aware of the risks to which they are exposed and that those municipalities with no plan in place are less aware or are unaware of these risks. We assume also that awareness of risk will affect the

Figure 3.5.1: Effect of a natural disaster on budget accounts according to implementation of a prevention plan



Notes: Estimation of the dynamic effect of a major natural disaster on the budgetary accounts of French municipalities with robust standard errors, using a staggered DiD event study methodology. The control variables include municipal budget items and municipal characteristics.

municipality’s budgetary situation. Implementing a prevention strategy and introducing efforts to mitigate the effects of a catastrophic event such as limitations on housing developments and investment in appropriate infrastructures in the most at risk areas will have some effect on the municipality’s budget.

We analyze the impact of natural disasters on the main budgetary accounts based on equation 3.1: total expenditure (figure 3.5.1a), total revenues (figure 3.5.1b), and total grants (figure 3.5.1c).

Figure 3.5.1a shows significant differences between the two groups. Group 1 is composed of 28,871 municipalities with no NHPP in place. Group 2 includes the 5,522 municipalities that have implemented an NHPP. We observe significantly increased expenditure for those municipalities in the former group although this effect seems to disappear three years after a shock. However, the same shock has no impact on total expenditure in municipalities with an NHPP.

However the same shock has no impact on total expenditure in municipalities

3.5. Effect of natural disaster on budget outcomes according to implementation of a prevention plan

with an NHPP. These results for total expenditures seem to indicate that prevention plans have a significant effect on budgetary decisions related to post-natural disaster management. The increase in spending in the two or three years after an event experienced by municipalities with no prevention strategy did not occur for those municipalities that anticipate and prepare for a shock.

Figure 3.5.1b focuses on total revenues. In municipalities with no NHPP, we observe a significant increase in total revenues in the first two years after a natural disaster event followed by a significant decrease. However, in municipalities with a pre-disaster prevention strategy, we observed no significant change following a disaster event. These results show that despite the costs related to implementing a prevention strategy, a natural disaster generates a decrease in total revenues likely due to a reduction in tax revenues following a disaster. However, our data do not allow us to disentangle among revenue sources

Figure 3.5.1c shows the effects of a natural disaster on total grants. We find that municipalities with no pre-disaster prevention plan experienced a small but significant increase in the amount of state grant funding in the three years after the shock, likely due to compensation to fund expenditure on recovery.

Those municipalities with an NHPP in place did not experience any increased grant funding. We can conclude that in the short term those municipalities that anticipated a shock and implemented disaster mitigation measures were not in need of grant aid. The increased demand from municipalities with no disaster prevention measures in place can be explained by the need for urgent investment to improve protection. Appendix table C.2 presents the results of the two way fixed effects estimation which are consistent with the DiD estimations with multiple treatment periods. To pursue the identification and better understand the interaction between the effect of a natural disaster in a municipality with a prevention plan, we estimate a triple difference model based on equation 3.2.

Table 3.5.1 columns 1, 2, and 3 present the respective results of the triple-difference model for expenditure, revenue, and grants.

The key variable of interest is the triple interaction “ $Treated \times Post \times NHPP$ ” which corresponds to the effect of implementation of a prevention plan in a municipality after the occurrence of a natural disaster. We observe that the coefficient of the triple interaction is not significant which confirms our previous results. A municipality with a prevention plan in place before the natural disaster occurred experiences no significant effect on its budget after the natural disaster, regarding municipalities which never experienced a disaster and had no prevention plan in place.

Our results confirm the effectiveness of natural hazard prevention plans for mitigating the impact of natural disasters on municipal budget accounts. Municipalities

with no prevention strategy experience significant problems related to recovering from a catastrophic event and absorbing the related shock. Crisis management seems more difficult and requires more budgetary resources.

These results are in line with those of Morvan (2022) for the French case and Masiero & Santarossa (2020) for the Italian case which show that over the long term municipal budgets are affected. However, municipalities covered by an NHPP do not experience the same impact on their budgetary positions. Prevention has a positive effect on the ability of municipalities to recover from a shock which offers opportunities for public policy.

Table 3.5.1: Triple difference estimation results

	Expenditures	Revenues	Grants
Post	0.010*** (0.003)	0.009*** (0.003)	0.007 (0.004)
NHPP	-0.009 (0.007)	-0.002 (0.007)	-0.002 (0.010)
Post×Treated	-0.001 (0.003)	-0.003 (0.003)	0.005 (0.004)
Post×NHPP	0.020** (0.006)	0.013* (0.006)	-0.008 (0.009)
Treated×NHPP	-0.019* (0.008)	-0.020* (0.008)	-0.011 (0.011)
Post×Treated ×NHPP	-0.014 (0.008)	-0.009 (0.007)	0.012 (0.010)
Time fixed effect	Yes	Yes	Yes
Municipal fixed effect	Yes	Yes	Yes
Municipal budget controls	Yes	Yes	Yes
Municipal characteristics controls	Yes	Yes	Yes
Observations	687,373	687,373	687,373
R ²	0.070	0.073	0.025

Notes: *p<0.05; **p<0.01; ***p<0.001; heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level. The control variables consist of municipal budget items (investment expenditures and debt), municipal characteristics controls (inter-municipal cooperation variable, and median income).

We conducted several tests to demonstrate the robustness of our results for the impact of a natural disaster on the municipality’s budgetary position. We started by conducting a falsification test to check for the presence of a placebo effect. We repeated the regressions used for the baseline results observing the year prior to the shock.

Graphs 3.5.1a, 3.5.1b and 3.5.1c show no significant effect on municipal accounts

3.5. Effect of natural disaster on budget outcomes according to implementation of a prevention plan

in the pre-shock periods. Again, similar to our baseline estimates, we conducted two-way fixed effects regressions observing the year prior to the shock to detect a possible effect (appendix table C.3). The results of this test show that there is no significant effect on municipal accounts in the year before the shock.

Appendix figures C.1 and C.2 confirm the common trend hypothesis. We constructed two graphs for the two sub-samples of municipalities with an NHPP and municipalities without an NHPP, and observed the pre-shock trends for the control and treatment groups. We observed peaks in 2007, 2013, and 2019. These three peaks are likely due to an increase in municipal spending in the year prior to a municipal election (2008, 2014, and 2020) which is in line with the findings in Beatriz (2019) and Foucault et al. (2008). We use time fixed effects to control for the electoral cycle.

One of the limitations of our research is that we do not control for natural disaster event intensity. Although the GASPAR data base does not provide information on the intensity, recall that article 1 in the July 13, 1982 law defines a natural disaster as a large and abnormal shock. Therefore, our sample does not include small shocks or average intensity events. However, to try to capture the level of the intensity in our sample, we constructed a restricted sample of the municipalities affected by storm Xynthia which was an exceptionally violent windstorm which affected Europe in 2010. Storm Xynthia crossed Western Europe between February 27th and March 1st 2010. The storm surge combined with high tides and large waves caused flood defenses along western France to fail. Over 50,000 ha of land were flooded and 47 people died as a result of the storm. Although the French departments of Vendée and Charente-Maritime suffered the most damage, it has been estimated that the cost of the damage caused by the flooding was in excess of €1.2 billion (Lumbroso & Vinet 2011). This event allows us to employ a two-way fixed effects model without the difficulty of multiple periods. The results of this estimate are in line with our main results (see appendix table C.4).

In addition, we extracted data from the Centre for Research on the Epidemiology of Disasters EM-DAT database. These international data selects catastrophic events of extreme intensity. EM-DAT records human and economic losses according to at least one of the following criteria: 10 fatalities, 100 affected people, declaration of a state of emergency, and calls for international assistance. We estimated the DiD model considering only these extreme events; the results were of a similar magnitude to the baseline results (see appendix figure C.3).

As a final robustness check, we test whether the results change depending on the nature of natural disaster - flood or drought for example (appendix table C.5). We employed two-way fixed effects since we had insufficient data to employ a multiple-period DiD estimation. Treatment assignment is based on type of disaster. We

chose to observe flood events and drought events which are the most frequent and the most contrasting disaster events experienced in France. The results for floods are mostly in line with the baseline results, with a slightly more intense effect than if we considered all disaster types. However, in the case of droughts, the impact on spending is not significant which might be because compared to floods droughts have a different short-term impact on municipalities. For instance, flooding might require evacuation of some of the population and might cause immediate material damage while a drought affects mainly agriculture and residential housing over the long-term which calls for a different budgetary response from the municipality.

3.6 Evidence on the impact of natural disasters on electoral outcomes

We investigated the impact of natural disasters on electoral outcomes for all incumbent mayors standing for re-election between 2008 and 2020.

The first part of table 3.6.1 presents the selection equation estimation results i.e. the probability of standing for re-election. Columns 1 and 2 present the results of the pooled estimates i.e. all mayors across all elections, columns 3-4, 5-6, and 7-8 are the 2020, 2014, and 2008 municipal elections. The results of the probit model (first part of table 3.6.1) for the probability that the incumbent mayor will run for re-election show no significant effect of a natural disaster event on the decision to run for re-election, and no effect of the existence of an NHPP for any election year.

However, in the pooled data, the interaction between a shock and implementation of an NHPP is significant. The probability of being a candidate is higher for incumbents who implemented a prevention plan and experienced a natural disaster.

In line with the findings in the literature (Cassette et al. 2013), we confirm that the municipal budget position plays a significant role in the willingness to stand for re-election as mayor. As expected, we found a positive impact of investment spending and a negative effect of debt on the probability of running for mayor. Moreover, the results show that the mayor's characteristics have an influence; it seems that gender and age affect the decision to run for re-election with male mayors and older mayors more keen to be re-elected. Finally, the number of competing candidates seems to have an ambiguous effect which can be positive or negative depending on the election considered.

The second part of table 3.6.1 presents the results for the second step in the Heckman model estimation i.e. the probability of re-election. The estimation results show that both experiencing a natural disaster and having a prevention plan have a significant effect. For each election, we find that a shock event has a negative effect on the probability of re-election i.e. the electorate tends to punish an incumbent if

a natural disaster event occurred during his or her previous term.

We observe also that in the two most recent elections having a natural hazard prevention plan had a negative effect on the re-election probability.⁷ However, the coefficient of the interaction between prevention plan and disaster event is not significant which means that citizens penalize mayors who implemented a prevention plan whether or not a natural disaster event occurred in the municipality. This result might be due to several mechanisms.

First, prevention policies might be misunderstood by inhabitants, and might be considered ineffective, unimportant or costly since the NHPP imposes some prohibitions on construction, includes some technical requirements for residential buildings, and requires specific infrastructures to protect against risk. House values are likely to be reduced if a municipality is identified officially as natural disaster prone; in the course of any house purchase transactions the buyer is informed about potential risks.

Similar to the results in the first part of table 3.6.1, the budget variables seem to have an effect on re-election, with debt in particular showing a significant negative effect. In the 2008 election we observe a positive impact on re-election of investment spending. Finally, re-election is affected by the characteristics of the incumbent mayor Male mayors and older aged mayors seem gender and older age seem to be more keen to be re-elected (see appendix table C.12 for the full results).

To check the effect of natural disasters on electoral results, we analyzed their sensitivity. We are interested in the timing of the natural disaster with respect to the election. We assume that the closer the shock to the municipal elections, the greater will be its influence on voter choices. In this section, our variables of interest are related to shocks that occurred during the electoral cycle, and one, two, and three years before the election. Appendix table C.6 presents the results for these different shock definitions. The estimated results confirm that a disaster has a significant and negative impact on the mayor's re-election and on implementation of a prevention plan, and the intensity of this effect increases for a disaster that occurred during the mayoral term.

We checked the sensitivity of our results to disaster intensity. Again, the data do not allow us to measure the intensity of the shock. However, using EM-DAT data we can identify particularly intense disasters (Xynthia storm, Roya flooding, etc.). Merging of the data available provides information on the municipalities affected by these major disasters.

Appendix table C.7 presents the results for these intense disasters and show that major disaster events have a negative and significant effect on mayoral re-election of

⁷We assume that since in 2008 very few municipalities (6,713 i.e. 20% of municipalities) had an NHHP, natural hazard prevention had not become a major issue for local residents.

Table 3.6.1: Heckman Model - Occurrence of natural disaster during the electoral cycle

	Pool			2020			2014			2008		
<i>Selection equation: candidate (0 or 1)</i>												
Shock	-0.008 (0.013)	-0.022 (0.014)	-0.013 (0.017)	-0.013 (0.018)	-0.005 (0.028)	-0.021 (0.033)	-0.021 (0.038)	-0.021 (0.038)	-0.021 (0.038)	-0.021 (0.038)	-0.037 (0.042)	-0.037 (0.042)
NHPP	-0.030 (0.018)	-0.072** (0.025)	-0.040 (0.025)	-0.039 (0.035)	0.023 (0.034)	-0.012 (0.049)	0.017 (0.050)	0.017 (0.050)	0.017 (0.050)	0.017 (0.050)	-0.032 (0.069)	-0.032 (0.069)
Shock× NHPP		0.087* (0.036)		-0.002 (0.049)		0.057 (0.071)		0.057 (0.071)		0.057 (0.071)	0.104 (0.099)	0.104 (0.099)
<i>Outcome equation: re-election (0 or 1)</i>												
Shock	-0.132*** (0.017)	-0.132*** (0.019)	-0.123*** (0.022)	-0.123*** (0.024)	-0.111*** (0.029)	-0.120*** (0.033)	-0.137** (0.047)	-0.137** (0.047)	-0.137** (0.047)	-0.137** (0.047)	-0.125* (0.050)	-0.125* (0.050)
NHPP	-0.121*** (0.023)	-0.122*** (0.032)	-0.106*** (0.032)	-0.107* (0.046)	-0.159*** (0.034)	-0.177*** (0.050)	0.017 (0.058)	0.017 (0.058)	0.017 (0.058)	0.017 (0.058)	0.061 (0.086)	0.061 (0.086)
Shock× NHPP		-0.001 (0.044)		0.002 (0.063)		0.017 (0.070)		0.017 (0.070)		0.017 (0.070)	-0.072 (0.117)	-0.072 (0.117)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal budget controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mayor's characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Political controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	54956	54956	27742	27742	21421	21421	5793	5793	5793	5793	5793	5793
Log Likelihood	-38540.99	-38537.81	-21730.48	-21730.48	-9583.302	-9575.287	-4820.489	-4820.489	-4820.489	-4820.489	-4818.918	-4818.918
ρ	-0.80 (0.101)	-0.80 (0.101)	-0.95 (0.178)	-0.94 (0.178)	-0.99 (0.0001)	-0.83 (0.027)	0.90 (0.040)	0.90 (0.040)	0.90 (0.040)	0.90 (0.040)	0.89 (0.040)	0.89 (0.040)

Notes: * p<0.05; ** p<0.01; *** p<0.001; heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level. The control variables consist of municipal budget items (investment expenditures and debt), municipal characteristics controls (inter-municipal cooperation variable, median income), and mayor's characteristics variables (incumbent's gender and age).

the same magnitude as in the baseline case. To refine our results, we ran the same analysis focusing on only two disaster types: flood and drought (appendix table C.8). In contrast to the effect of budget, we observe that regardless of the type of disaster, the effect on re-election is negative and significant. We also examined the effects of municipality and voting type heterogeneity. We examined municipalities governed by a proportional list system (appendix table C.9), and those governed by a multi-member system (appendix table C.10), which include the smallest municipalities.

To further refine the analysis, for the largest municipalities i.e. those with a proportional list system, we constructed sub-samples based on numbers of inhabitants (more than 10,000, between 10,000 and 3,500, and less than 3,500). Appendix table C.9 shows a positive and significant effect for communes with fewer than 3,500 inhabitants. In the case of those with more than 3,500 inhabitants we observe no effect of a natural disaster on re-election although they are influenced by the budgetary variables and the mayor's characteristics. We also analyzed the effect of a natural disaster on the smallest municipalities i.e. those with fewer than 1,000 inhabitants after 2014 and fewer than 3,500 inhabitants in 2008. These are a special case since most incumbent mayors run for election again which rules out use of a two-stage model. We chose to use the classical probit model. Appendix table C.10 shows that a shock has a negative effect on the probability of re-election but the investment and mayor characteristics are significantly positive. The sample of municipalities with a list-based electoral system enables us also to analyze several political variables. Appendix table C.9 presents the results for this sub-sample which controls for political alignment with central government, political color, and electoral competition. These political variables play a role in candidacy and re-election. Politically affiliated mayors are more likely to be candidates than non-affiliated mayors. However, political affiliation does not have significant effect on re-election probability. In addition, strong electoral competition i.e. a small vote gap between the two lists resulting from the first round, has a positive effect on re-election. However, the inclusion of these political variables does not alter the main results. Finally, we excluded the control variables to avoid possible endogeneity caused by a natural disaster event on the other variables since a natural disaster affects the municipality's budget which might bias the estimated effect of these variables on candidacy and re-election. When we removed the budget variables, the magnitude of the effects of the shock did not change (appendix table C.11).

3.7 Conclusion

In this study, we investigated the causal impact of natural disasters on electoral outcomes using French municipal data. We applied a Heckman model to avoid

selection bias and to estimate the probability of re-election at the municipal level in the event of a natural disaster. We analyzed all French municipalities over three municipal elections, 2008, 2014, and 2020. The advantage of our model is that it allows us to account for the endogeneity of the individual incumbent mayor's decision to run again or not. We found that the occurrence of heterogeneous natural disasters significantly reduces the re-election chances of the incumbent mayor. This result is in line with those in Gasper & Reeves (2011) and shows that French voters are a responsive electorate or (to use Achen & Bartels 2016's terminology) are egotropic retrospective voters, i.e. they react to events without observing the responsibilities of the leaders.

Although we show that an NHPP has a very strong and positive effect on local budget accounts its implementation is not rewarded in citizens' electoral choices. The chances of re-election is reduced for mayors of municipalities with prevention strategies in place. This supports the idea of myopia: voters reward incumbents for delivering investment spending or reducing debt but penalize them for investing in disaster preparedness.

Not only do voters not perceive the short-term and long-term benefits of prevention policies on local budgets they also punish decision-makers for implementing costly policies, and for building construction rules and regulations that might decrease the value of their housing. This last finding needs more investigation using data on house prices and prevention policies. However, in the context of public policy, we provide evidence on the lack of efficacy of elections to persuade incumbent mayors to implement efficient natural disaster prevention measures.

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Chapter 3. Natural disasters and voter gratitude: What is the role of prevention policies?

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C Appendix

C.1 Descriptive statistics

Table C.1: Descriptive statistics

FULL SAMPLE	Obs.	Mean	Std Dev	Min	Max
Political variables					
1 if the incumbent is candidate	90,083	0.67	0.47	0	1
1 if the incumbent is reelected	100,282	0.58	0.49	0	1
Incumbent share of votes (at the decisive round)	76,098	75.78	14.43	26.83	99.78
Share of votes for president	106,679	53.96	12.43	0.00	100
Closeness (at the first round)	22,001	46.97	38.69	0.01	100
Mayor's political affiliation:	22,001				
• far left	179				
• left	5,210				
• center	578				
• right	9,239				
• far right	32				
• other	5,240				
Natural disasters and prevention variables					
1 if a natural disaster occurred during the election cycle	107,158	0.33	0.47	0	1
1 if a natural disaster has occurred in the year preceding the election	107,158	0.12	0.33	0	1
1 if the incumbent has implemented a prevention plan	108,133	0.12	0.33	0	1
Spending variables					
Investment expenditure (per capita)	107,158	448.7	704.98	0	58,888
Debt of the municipality (per capita)	107,158	599.5	1242.37	0	158,577
Incumbent controls					
Mayor's vote share at the previous election	34,987	75.34	15.34	15.79	100
1 if the mayor was elected in the first round of the preceding election	34,988	0.95	0.21	0	1
Number of consecutive mandates	104,202	0.96	1.12	0	6
Mayor's characteristics					
Age of incumbent mayor	85,710	58.45	9.54	20	98
1 if the incumbent is a man	103,045	0.83	0.37	0	1
Municipal characteristics					
Population	107,158	1,729	10,794.87	1	859,367
Median income	98,089	21,628.8	9,329	12.8	354,406
Type of inter-municipal cooperation:	107,156				
• isolated municipality	86,386				
• community of municipalities	2,889				
• highly integrated municipalities	17,512				

C.2 Additional results: Effect on municipal accounts

Two way Fixed Effect model

Table C.2: Impact of natural disasters on local government accounts according to their adherence to a NHPP: TWFE

	<i>Fixed Effect model - Within Estimator</i>											
	Total Expenditure		Total Revenues				Total grants				Debt	
	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP		
Full sample												
Shock _t	-0.006 (0.004)	0.010*** (0.002)	-0.007* (0.004)	0.009*** (0.002)	0.008 (0.007)	-0.003 (0.003)	0.007 (0.032)	0.038** (0.015)				
Shock _{t-1}	0.002 (0.005)	0.007*** (0.002)	-0.001 (0.004)	0.005** (0.002)	0.012 (0.008)	0.004 (0.003)	0.020 (0.035)	0.042** (0.016)				
Shock _{t-2}	0.002 (0.005)	0.006** (0.002)	-0.001 (0.005)	0.004** (0.002)	0.009 (0.008)	0.017*** (0.003)	0.035 (0.038)	0.041** (0.018)				
Shock _{t-3}	-0.003 (0.005)	0.006** (0.002)	-0.004 (0.005)	0.004* (0.002)	0.009 (0.009)	0.017*** (0.004)	0.006 (0.040)	0.042** (0.019)				
Shock _{t-4}	0.0003 (0.006)	0.003 (0.003)	-0.001 (0.006)	0.001 (0.002)	0.008 (0.011)	0.015*** (0.004)	0.042 (0.042)	0.030 (0.019)				
Shock _{t-5}	-0.006 (0.006)	0.004 (0.003)	-0.012** (0.006)	0.002 (0.002)	0.010 (0.011)	0.010*** (0.004)	0.034 (0.047)	0.021 (0.020)				
Shock _{t-6}	-0.0004 (0.007)	0.002 (0.003)	-0.011* (0.006)	-0.001 (0.003)	0.003 (0.012)	0.012*** (0.004)	0.007 (0.052)	-0.001 (0.021)				
Shock _{t-7}	-0.011 (0.007)	0.003 (0.003)	-0.007 (0.007)	0.004 (0.003)	0.012 (0.012)	0.013*** (0.004)	0.029 (0.055)	-0.005 (0.022)				
Shock _{t-8}	-0.001 (0.008)	-0.003 (0.003)	-0.002 (0.008)	0.001 (0.003)	0.018 (0.012)	0.013*** (0.005)	0.0002 (0.058)	-0.025 (0.022)				
Shock _{t-9}	-0.013 (0.008)	0.003 (0.003)	-0.006 (0.008)	-0.001 (0.003)	0.036*** (0.013)	0.014*** (0.005)	0.044 (0.061)	-0.039* (0.022)				
Shock _{t-10}	-0.001 (0.010)	0.002 (0.004)	-0.005 (0.009)	0.001 (0.003)	0.029* (0.017)	0.009 (0.005)	0.055 (0.062)	-0.005 (0.022)				
Observations	103,706	525,538	103,706	525,538	103,706	525,538	103,706	525,538				
R ²	0.158	0.190	0.194	0.242	0.104	0.108	0.1010	0.1010				
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				

Notes: * p<0.05; ** p<0.01; *** p<0.001; All models control for budgetary 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), socio-economic (median income and percent of unemployment) and socio-demographic 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 an 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 an NHPP after the shock.

Placebo test and common trend

Table C.3: Impact of natural disasters on local government accounts according to their adherence to a NHPP: Placebo test

	Full Sample						Xynthia Sample					
	Total Expenditure			Total Revenues			Total Expenditure			Total Revenues		
	NHPP	No NHPP		NHPP	No NHPP		NHPP	No NHPP		NHPP	No NHPP	
Shock _{t+1}	-0.0002 (0.005)	0.003 (0.003)		-0.002 (0.005)	0.005 (0.002)		0.054 (0.033)	0.001 (0.009)		0.046 (0.032)	-0.003 (0.008)	
Shock _t	-0.005 (0.004)	0.010*** (0.002)		-0.004 (0.004)	0.009*** (0.002)		0.0001 (0.022)	0.009 (0.007)		-0.015 (0.023)	0.009 (0.006)	
Shock _{t-1}	0.003 (0.004)	0.007*** (0.002)		0.001 (0.004)	0.005*** (0.002)		0.015 (0.025)	0.016* (0.007)		0.001 (0.024)	0.007 (0.006)	
Shock _{t-2}	0.004 (0.005)	0.006*** (0.002)		0.001 (0.004)	0.004* (0.002)		0.011 (0.025)	0.028*** (0.007)		-0.001 (0.025)	0.018* (0.007)	
Shock _{t-3}	-0.002 (0.005)	0.005* (0.002)		-0.002 (0.005)	0.004 (0.002)		-0.004 (0.026)	0.021*** (0.008)		-0.022 (0.023)	0.021*** (0.007)	
Shock _{t-4}	0.002 (0.005)	0.003 (0.002)		0.001 (0.005)	0.001 (0.002)		0.016 (0.030)	0.030*** (0.008)		0.042 (0.031)	0.025*** (0.007)	
Shock _{t-5}	-0.004 (0.005)	0.004 (0.002)		-0.010 (0.005)	0.002 (0.002)		-0.019 (0.029)	0.025*** (0.008)		-0.019 (0.033)	0.015 (0.008)	
Observations	113,405	515,866		113,405	515,866		39,378	187,680		39,378	187,680	
R ²	0.154	0.191		0.189	0.244		0.032	0.038		0.043	0.047	

Notes: *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 unemployment) and socio-demographic 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 an 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 an NHPP after the shock.

Intensity Analysis

Table C.4: Impact of natural disasters on local government accounts according to their adherence to a NHPP: Xynthia Storm

	<i>Fixed Effect model - Within Estimator</i>							
	Total Expenditure		Total Revenues		Total grants		Debt	
	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP
Panel: Xynthia Storm sample								
Xynthia _t	-0.013 (0.022)	0.021** (0.008)	-0.021 (0.023)	0.025*** (0.007)	-0.005 (0.027)	0.058*** (0.008)	0.006 (0.150)	0.048 (0.042)
Xynthia _{t-1}	0.002 (0.027)	0.028*** (0.007)	-0.005 (0.025)	0.023*** (0.007)	0.001 (0.031)	0.061*** (0.009)	0.046 (0.111)	0.015 (0.043)
Xynthia _{t-2}	-0.001 (0.026)	0.040*** (0.008)	-0.007 (0.026)	0.034*** (0.008)	-0.0002 (0.032)	0.079*** (0.009)	0.070 (0.122)	0.008 (0.048)
Xynthia _{t-3}	-0.017 (0.028)	0.033*** (0.008)	-0.027 (0.026)	0.037*** (0.008)	-0.064 (0.034)	0.071*** (0.010)	0.130 (0.147)	0.004 (0.053)
Xynthia _{t-4}	0.004 (0.032)	0.043*** (0.009)	0.036 (0.034)	0.041*** (0.008)	-0.078 (0.049)	0.080*** (0.010)	0.167 (0.192)	0.001 (0.054)
Xynthia _{t-5}	-0.032 (0.032)	0.038*** (0.010)	-0.025 (0.035)	0.032*** (0.009)	-0.050 (0.047)	0.062*** (0.012)	-0.092 (0.261)	-0.082 (0.061)
Xynthia _{t-6}	-0.057 (0.034)	0.039*** (0.010)	-0.056 (0.033)	0.043*** (0.010)	-0.099 (0.105)	0.099*** (0.013)	0.012 (0.202)	-0.122 (0.064)
Xynthia _{t-7}	-0.022 (0.046)	0.035** (0.012)	0.034 (0.049)	0.047*** (0.011)	-0.038 (0.097)	0.079*** (0.016)	-0.085 (0.267)	-0.162* (0.068)
Xynthia _{t-8}	-0.015 (0.052)	0.021* (0.012)	0.006 (0.046)	0.045*** (0.011)	-0.010 (0.105)	0.077** (0.024)	-0.055 (0.314)	-0.250** (0.077)
Xynthia _{t-9}	-0.008 (0.065)	0.056** (0.015)	0.051 (0.060)	0.058*** (0.014)	0.054 (0.132)	0.114*** (0.021)	-0.091 (0.256)	-0.307*** (0.090)
Observations	39,378	187,680	39,378	187,680	39,379	187,680	39,378	187,680
R ²	0.032	0.038	0.043	0.047	0.090	0.092	0.005	0.003
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

Notes: *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 unemployment) and socio-demographic 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 an 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 an NHPP after the shock.

Type of shocks

Table C.5: Regression Results according to type of shocks

<i>Fixed Effect model - Within Estimator</i>								
	Total Expenditure		Total Revenues		Total grants		Debt	
	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP	NHPP	No NHPP
Flood								
Shock _τ	-0.003 (0.006)	0.015*** (0.003)	-0.005 (0.006)	0.014*** (0.003)	0.007 (0.012)	-0.002 (0.005)	0.018 (0.049)	0.042 (0.022)
Shock _{τ-1}	0.011 (0.007)	0.019*** (0.003)	0.006 (0.006)	0.012*** (0.003)	0.027* (0.012)	0.007 (0.005)	0.017 (0.053)	0.059* (0.023)
Shock _{τ-2}	0.007 (0.007)	0.016*** (0.003)	0.003 (0.007)	0.011*** (0.003)	0.012 (0.012)	0.016*** (0.005)	0.049 (0.056)	0.061* (0.026)
Shock _{τ-3}	-0.008 (0.007)	0.005 (0.003)	-0.007 (0.007)	0.005 (0.003)	0.022 (0.013)	0.021*** (0.005)	0.008 (0.060)	0.050 (0.026)
Shock _{τ-4}	-0.011 (0.009)	0.003 (0.004)	-0.010 (0.008)	-0.002 (0.003)	0.006 (0.017)	0.022*** (0.005)	0.027 (0.061)	0.026 (0.026)
Shock _{τ-5}	-0.005 (0.009)	0.012*** (0.004)	-0.011 (0.008)	0.006* (0.003)	0.012 (0.017)	0.013* (0.005)	0.038 (0.066)	0.006 (0.027)
Shock _{τ-6}	0.005 (0.010)	0.006 (0.004)	-0.004 (0.009)	0.005 (0.004)	0.005 (0.020)	0.009 (0.006)	-0.018 (0.074)	-0.023 (0.028)
Shock _{τ-7}	-0.003 (0.011)	0.006 (0.004)	-0.005 (0.010)	0.003 (0.004)	0.021 (0.019)	0.011 (0.006)	-0.005 (0.079)	-0.021 (0.028)
Shock _{τ-8}	-0.011 (0.011)	0.001 (0.004)	-0.010 (0.010)	-0.001 (0.004)	0.039* (0.018)	0.010 (0.007)	-0.055 (0.084)	-0.039 (0.029)
Shock _{τ-9}	-0.035*** (0.011)	0.003 (0.004)	-0.018 (0.011)	-0.001 (0.004)	0.051*** (0.018)	0.015* (0.006)	0.006 (0.083)	-0.065* (0.029)
Observations	63,147	333,980	63,147	333,980	63,147	333,980	63,147	333,980
R ²	0.151	0.189	0.186	0.240	0.089	0.097	0.010	0.010
Drought								
Shock _τ	-0.011 (0.012)	0.003 (0.006)	-0.008 (0.012)	0.004 (0.005)	0.039 (0.030)	-0.012 (0.013)	0.001 (0.067)	0.011 (0.036)
Shock _{τ-1}	-0.031* (0.014)	-0.016* (0.007)	-0.015 (0.012)	-0.006 (0.006)	0.010 (0.031)	-0.014 (0.015)	0.057 (0.084)	0.040 (0.042)
Shock _{τ-2}	-0.012 (0.019)	-0.014 (0.009)	-0.003 (0.016)	-0.014 (0.007)	-0.049 (0.033)	0.006 (0.015)	0.076 (0.110)	0.022 (0.050)
Shock _{τ-3}	0.029 (0.020)	-0.004 (0.008)	0.013 (0.019)	-0.012 (0.007)	-0.007 (0.037)	0.017 (0.015)	0.205* (0.119)	0.035 (0.053)
Shock _{τ-4}	0.020 (0.021)	-0.002 (0.008)	0.005 (0.020)	-0.006 (0.007)	-0.052 (0.037)	-0.005 (0.015)	0.166 (0.120)	0.013 (0.056)
Shock _{τ-5}	0.013 (0.018)	-0.011 (0.008)	0.002 (0.016)	-0.007 (0.007)	-0.011 (0.038)	0.016 (0.014)	0.202 (0.131)	0.053 (0.055)
Shock _{τ-6}	-0.006 (0.023)	-0.010 (0.008)	-0.012 (0.020)	-0.018* (0.007)	-0.047 (0.043)	0.019 (0.015)	0.131 (0.149)	0.074 (0.055)
Shock _{τ-7}	-0.030 (0.020)	-0.012 (0.009)	-0.013 (0.020)	-0.013 (0.008)	-0.034 (0.046)	0.014 (0.015)	0.209 (0.136)	0.057 (0.055)
Shock _{τ-8}	0.017 (0.025)	-0.027*** (0.009)	-0.001 (0.022)	-0.011 (0.008)	0.008 (0.043)	0.036* (0.018)	0.190 (0.147)	0.023 (0.056)
Shock _{τ-9}	0.014 (0.030)	-0.012 (0.010)	0.013 (0.026)	-0.011 (0.008)	-0.026 (0.047)	-0.017 (0.017)	0.225 (0.176)	0.068 (0.054)
Observations	38,323	222,709	38,323	222,709	38,323	222,709	38,323	222,709
R ²	0.163	0.201	0.203	0.261	0.058	0.063	0.010	0.010

Notes: *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 unemployment) and socio-demographic 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 an 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 an NHPP after the shock.

Figure C.1: Common trend before shock - general case without NHPP

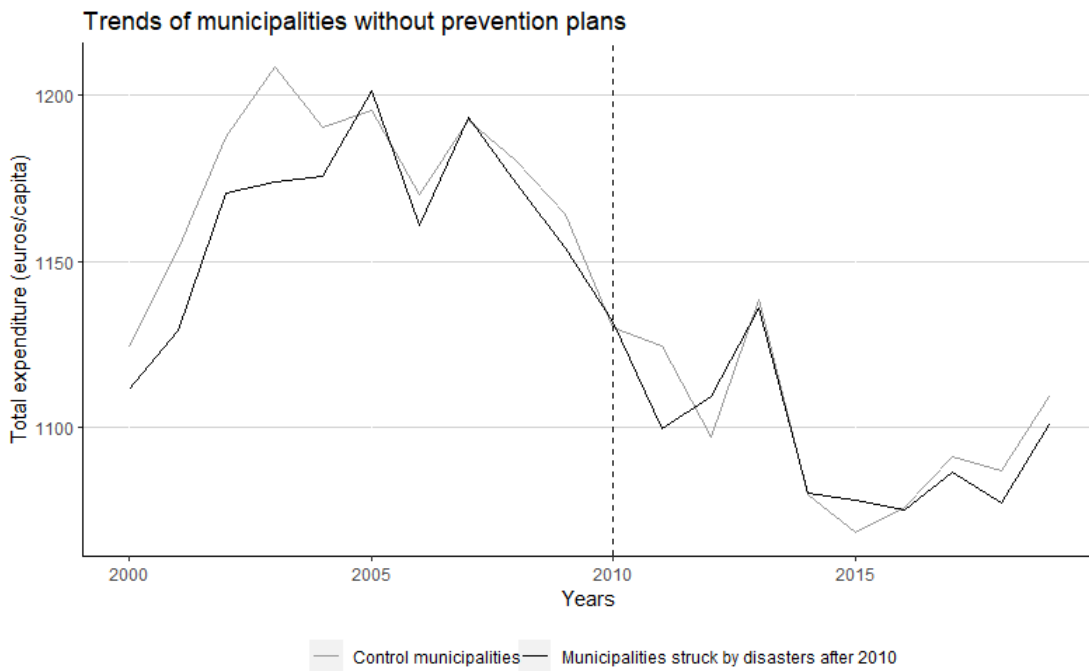


Figure C.2: Common trend before shock - general case with NHPP

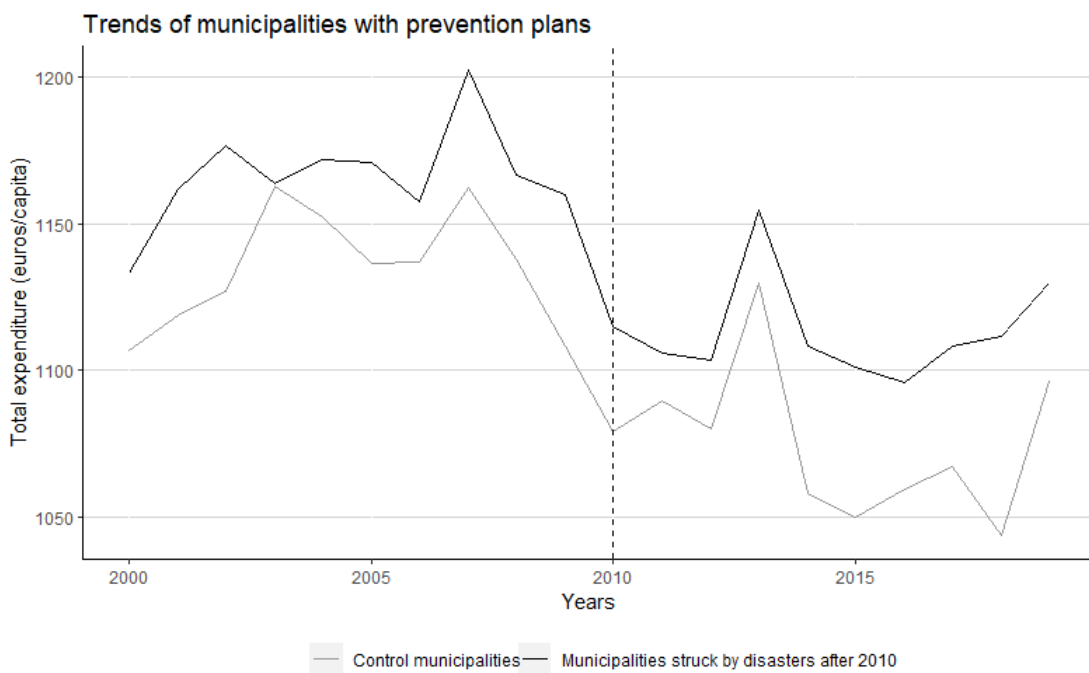
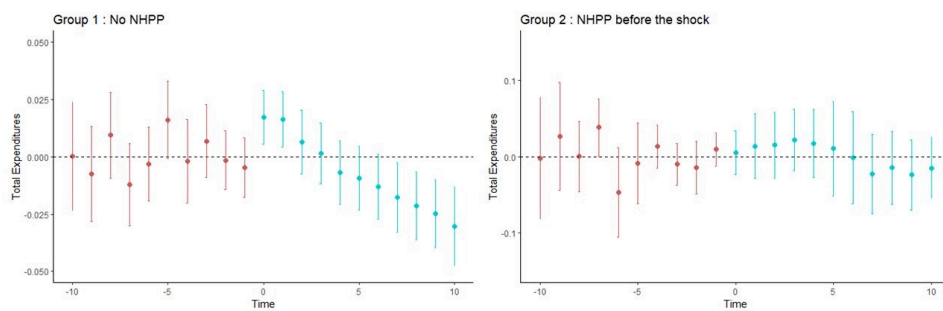
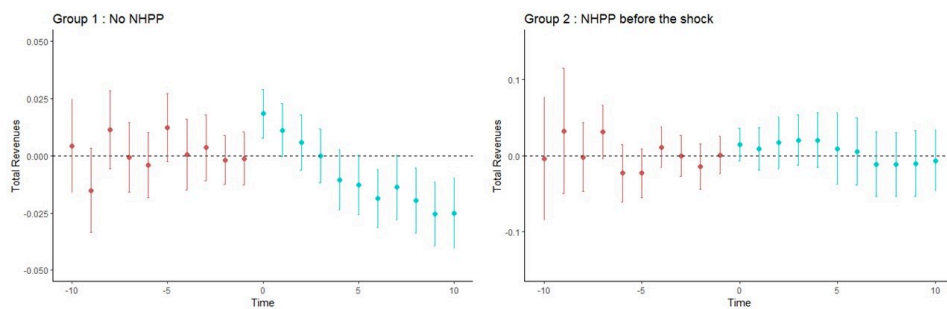


Figure C.3: Impact of natural disasters on local government accounts according to their adherence to a NHPP: major natural disaster

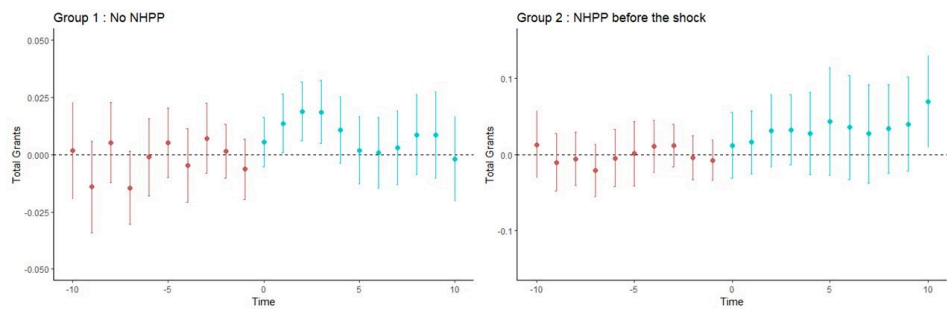
(a) Expenditures



(b) Revenues



(c) Grants



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

C.3 Additional results: Electoral outcomes

Sensitivity analysis

Table C.6: Heckman Model - Occurrence of natural disaster at different times in the cycle

Pooling						
The shock occurred before the election:						
	1 year before	2 years before	3 years before	4 years before	5 years before	during the cycle
<i>Selection equation: candidate (1 or 0)</i>						
Shock	0.045*	0.021	0.006	-0.018	-0.009	-0.010
	(0.018)	(0.015)	(0.014)	(0.014)	(0.013)	(0.013)
NHPP	-0.039*	-0.038*	-0.038*	-0.036*	-0.037*	-0.036*
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
<i>Outcome equation: re-election</i>						
Shock	-0.115***	-0.126***	-0.141***	-0.154***	-0.127***	-0.127***
	(0.022)	(0.019)	(0.018)	(0.018)	(0.017)	(0.017)
NHPP	-0.114***	-0.111***	-0.104***	-0.105***	-0.104***	-0.104***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Municipal budget controls	Yes	Yes	Yes	Yes	Yes	Yes
Municipal characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes
Mayor's characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	54920	54920	54920	54920	54920	54920
Log Likelihood	-38500.56	-38493.85	-38484.64	-38472.73	-38486.09	-38485.6
ρ	-0.735	-0.728	-0.723	-0.721	-0.735	-0.737
	(0.082)	(0.083)	(0.085)	(0.087)	(0.087)	(0.087)
Pooling						
The shock occurred before the election:						
	1 year before	2 years before	3 years before	4 years before	5 years before	during the cycle
<i>Selection equation: candidate (0 or 1)</i>						
Shock	0.040*	0.014	-0.003	-0.025	-0.018	-0.019
	(0.019)	(0.016)	(0.015)	(0.015)	(0.014)	(0.014)
NHPP	-0.044*	-0.056**	-0.065**	-0.064**	-0.075**	-0.072**
	(0.020)	(0.021)	(0.023)	(0.024)	(0.025)	(0.025)
Shock \times NHPP	0.068	0.083*	0.089*	0.083*	0.096**	0.089*
	(0.047)	(0.040)	(0.037)	(0.037)	(0.036)	(0.036)
<i>Outcome equation: re-election (0 or 1)</i>						
Shock	-0.118***	-0.128***	-0.147***	-0.160***	-0.134***	-0.136***
	(0.024)	(0.021)	(0.020)	(0.019)	(0.019)	(0.019)
NHPP	-0.114***	-0.106***	-0.106***	-0.112***	-0.112***	-0.116***
	(0.025)	(0.027)	(0.030)	(0.030)	(0.032)	(0.032)
Shock \times NHPP	-0.072	-0.063	-0.031	-0.020	-0.015	-0.005
	(0.053)	(0.047)	(0.045)	(0.044)	(0.044)	(0.044)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Municipal budget controls	Yes	Yes	Yes	Yes	Yes	Yes
Municipal characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes
Mayor's characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	54920	54920	54920	54920	54920	54920
Log Likelihood	-38520.42	-38512.36	-38502.18	-38491.53	-38504.71	-38504.65
ρ	-0.80	-0.79	-0.79	-0.79	-0.80	-0.81
	(0.093)	(0.097)	(0.101)	(0.104)	(0.101)	(0.101)

Notes: *p<0.05; **p<0.01; ***p<0.001; heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level. The control variables consist of municipal budget elements (investment expenditures and debt), municipal characteristics controls (inter-municipal cooperation variable, median income), and mayor's characteristics variables (incumbent's gender and age).

Table C.7: Heckman Model - Occurrence of a major natural disaster during the election cycle

	Major natural disaster							
	Pool		2020		2008			
<i>Selection equation: candidate (1 or 0)</i>								
Shock	0.039 (0.024)	0.011 (0.025)	0.028 (0.027)	0.015 (0.029)	-0.015 (0.057)	-0.021 (0.060)	-0.089 (0.103)	-0.148 (0.114)
NHPP	-0.035 (0.024)	-0.065* (0.026)	-0.008 (0.032)	-0.028 (0.035)	0.003 (0.047)	-0.001 (0.050)	-0.024 (0.067)	-0.047 (0.070)
Shock × NHPP		0.214** (0.072)		0.102 (0.082)	0.044 (0.169)			0.359 (0.264)
<i>Outcome equation: re-election</i>								
Shock	-0.138*** (0.030)	-0.130*** (0.032)	-0.132*** (0.034)	-0.120** (0.037)	-0.158** (0.057)	-0.157* (0.061)	-0.301** (0.107)	-0.319** (0.119)
NHPP	-0.132*** (0.031)	-0.124*** (0.033)	-0.128** (0.040)	-0.110* (0.046)	-0.164*** (0.048)	-0.163** (0.050)	0.046 (0.076)	0.040 (0.081)
Shock × NHPP		-0.067 (0.080)		-0.081 (0.095)		-0.013 (0.170)		0.095 (0.241)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal budget controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mayor's characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	38048	38048	18705	18705	15375	15375	3968	3968
Log Likelihood	-25741.5	-25736.34	-14434.67	-14433.72	-6321.366	-6321.328	-3249.475	-3248.44
ρ	0.71 (0.121)	0.72 (0.125)	-0.99 (0.0003)	-0.99 (0.0002)	0.82 (0.030)	0.82 (0.030)	0.94 (0.032)	0.94 (0.032)

Notes: * p<0.05; ** p<0.01; *** p<0.001; heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level. The control variables consist of municipal budget elements (investment expenditures and debt), municipal characteristics controls (inter-municipal cooperation variable, median income), and mayor's characteristics variables (incumbent's gender and age).

Appendix

Table C.8: Heckman Model - Occurrence of natural disaster during the electoral cycle: Types of shock

	Flood							
	Pool		2020		2014		2008	
<i>Selection equation: candidate (0 or 1)</i>								
Shock	-0.015 (0.015)	-0.027 (0.016)	-0.065** (0.020)	-0.034 (0.022)	0.004 (0.031)	-0.006 (0.035)	-0.048 (0.043)	-0.062 (0.048)
NHPP	-0.044* (0.020)	-0.070** (0.025)	-0.073** (0.027)	-0.041 (0.035)	0.016 (0.038)	-0.003 (0.049)	-0.014 (0.054)	-0.043 (0.069)
Shock× NHPP		0.069 (0.041)		-0.029 (0.058)		0.044 (0.077)		0.075 (0.109)
<i>Outcome equation: re-election (0 or 1)</i>								
Shock	-0.137*** (0.019)	-0.141*** (0.021)	-0.151*** (0.026)	-0.148*** (0.029)	-0.119*** (0.031)	-0.124*** (0.035)	-0.178*** (0.053)	-0.180** (0.057)
NHPP	-0.108*** (0.025)	-0.118*** (0.033)	-0.117*** (0.035)	-0.109* (0.045)	-0.155*** (0.037)	-0.165*** (0.050)	0.051 (0.063)	0.050 (0.086)
Shock× NHPP		0.021 (0.049)		0.020 (0.074)		0.020 (0.075)		0.009 (0.127)
Observations	47966	47966	24795	22620	20175	20175	5171	5171
Log Likelihood	-32975.88	-32974.08	-19150.84	-17701	-8785.587	-8785.339	-4296.008	-4295.701
ρ	-0.75 (0.103)	-0.75 (0.104)	-0.93 (0.081)	-0.96 (0.104)	-0.85 (0.027)	-0.85 (0.027)	0.90 (0.045)	0.90 (0.045)

	Drought							
	Pool		2020		2014		2008	
<i>Selection equation: candidate (0 or 1)</i>								
Shock	0.029 (0.017)	0.007 (0.018)	0.002 (0.020)	-0.009 (0.021)	-0.007 (0.043)	-0.012 (0.050)	0.041 (0.054)	0.024 (0.059)
NHPP	-0.032 (0.021)	-0.075** (0.025)	-0.009 (0.027)	-0.039 (0.035)	0.003 (0.043)	-0.002 (0.050)	-0.024 (0.058)	-0.044 (0.069)
Shock× NHPP		0.127** (0.044)		0.078 (0.056)		0.019 (0.098)		0.088 (0.126)
<i>Outcome equation: re-election (0 or 1)</i>								
Shock	-0.166*** (0.022)	-0.163*** (0.024)	-0.141*** (0.026)	-0.140*** (0.028)	-0.233*** (0.043)	-0.235*** (0.050)	-0.072 (0.061)	-0.034 (0.067)
NHPP	-0.126*** (0.026)	-0.120*** (0.033)	-0.112** (0.035)	-0.107* (0.047)	-0.161*** (0.043)	-0.163** (0.050)	-0.019 (0.066)	0.052 (0.083)
Shock× NHPP		-0.019 (0.053)		-0.013 (0.069)		0.006 (0.095)		-0.181 (0.141)
Observations	44382	44382	23372	23372	16346	16346	4664	4664
Log Likelihood	-30853.01	-30848.52	-18174.84	-18173.82	-6922.911	-6922.883	-3830.834	-3828.353
ρ	-0.73 (0.119)	-0.73 (0.104)	-0.89 (0.123)	-0.89 (0.023)	-0.85 (0.033)	-0.85 (0.033)	0.92 (0.035)	0.92 (0.035)

Notes: *p<0.05; **p<0.01; ***p<0.001 ; All control variables are listed in the table above. Heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level. The control variables consist of municipal budget elements (investment expenditures and debt), municipal characteristics controls (inter-municipal cooperation variable, median income), and mayor's characteristics variables (incumbent's gender and age).

Heterogeneity analysis

Table C.9: Heckman Model - Political variables - Sample with proportional, list, two-round voting system

	All municipalities	> 10000	10000 < & > 3500	< 3500
<i>Selection equation: candidate (0 or 1)</i>				
Shock	0.068*** (0.020)	-0.049 (0.069)	0.037 (0.041)	0.116*** (0.024)
NHPP	-0.037 (0.023)	0.046 (0.069)	0.104* (0.048)	-0.082** (0.030)
Vote share for president	-0.000 (0.001)	0.006* (0.003)	0.003 (0.002)	-0.002 (0.001)
Political Color: Far Left	0.688*** (0.129)			
Political Color: Left	0.398*** (0.041)			
Political Color: Center	0.219** (0.068)			
Political Color: Right	0.303*** (0.037)			
Political Color: Far Right	0.217 (0.233)			
Nb. Competitors	-0.020* (0.009)	-0.061** (0.021)	-0.167*** (0.020)	-0.138*** (0.018)
<i>Outcome equation: re-election (0 or 1)</i>				
Shock	-0.083*** (0.025)	0.111 (0.071)	-0.003 (0.046)	-0.114** (0.043)
NHPP	-0.224*** (0.028)	-0.116 (0.075)	-0.025 (0.054)	-0.459*** (0.042)
Vote share for president	-0.002 (0.001)	-0.006* (0.003)	-0.001 (0.002)	-0.002 (0.002)
Political Color: Far Left	-0.001 (0.147)			
Political Color: Left	0.084 (0.050)			
Political Color: Center	0.059 (0.081)			
Political Color: Right	-0.055 (0.045)			
Political Color: Far Right	-0.049 (0.254)			
Closeness	0.016*** (0.001)	0.029*** (0.003)	0.020*** (0.002)	0.016*** (0.001)
Time fixed effect	Yes	Yes	Yes	Yes
Municipal budget controls	Yes	Yes	Yes	Yes
Municipal characteristics controls	Yes	Yes	Yes	Yes
Mayor's characteristics controls	Yes	Yes	Yes	Yes
Observations	20732	2203	4709	13820
Log Likelihood	-17025.1	-1772.363	-4043.605	-10903.89
ρ	-0.84 (0.035)	-0.849 (0.164)	-0.88 (0.034)	0.18 (0.298)

Notes: *p<0.05; **p<0.01; ***p<0.001 ; heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level. The control variables consist of municipal budget elements (investment expenditures and debt), municipal characteristics controls (inter-municipal cooperation variable, median income), and mayor's characteristics variables (incumbent's gender and age).

Table C.10: Probit Model - Occurrence of natural disaster during the electoral cycle
 - all candidates, regardless of competition - Sample with majority, multi-member,
 two-round system

	Sample with majority, multi-member, two-round system			
	pool	2020	2014	2008
<i>Outcome equation: re-election (1 or 0)</i>				
Shock	-0.032** (0.012)	-0.049* (0.020)	0.000 (0.020)	-0.073** (0.023)
NHPP	-0.024 (0.017)	-0.115*** (0.032)	0.053 (0.027)	-0.022 (0.032)
Time fixed effect	Yes			
Municipal budget controls	Yes	Yes	Yes	Yes
Municipal characteristics controls	Yes	Yes	Yes	Yes
Mayor's characteristics controls	Yes	Yes	Yes	Yes
Observations	56218	19434	21647	15136
Log Likelihood	-35193.598	-11365.661	-13924.435	-9836.5422
Pseudo R2	0.0682	0.0831	0.0551	0.0531

Notes: *p<0.05; **p<0.01; ***p<0.001 ; All control variables are listed in the table above. Heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level.

Table C.11: Heckman Model - Occurrence of natural disaster during the electoral cycle: control variables

	Pooling				
<i>Selection equation: candidate (1 or 0)</i>					
Shock	0.017 (0.013)	0.022 (0.013)	-0.012 (0.012)	-0.001 (0.011)	-0.020* (0.010)
NHPP	-0.102*** (0.018)	-0.102*** (0.018)	-0.137*** (0.017)	-0.101*** (0.016)	-0.116*** (0.014)
Inv. Expenditure	0.115*** (0.007)				
Debt	-0.013*** (0.004)				
EPCI (Integrated)	-0.146*** (0.015)	-0.145*** (0.015)			
EPCI (Isolated)	-0.099 (0.064)	-0.057 (0.064)			
Median Income	0.057*** (0.013)	0.053*** (0.013)			
Inc. gender	0.210*** (0.016)	0.214*** (0.016)	0.195*** (0.015)		
Inc. age	-0.015** (0.006)	-0.014* (0.006)	-0.013* (0.005)		
Inc. age2	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)		
Vote share for president	0.002** (0.001)	0.002*** (0.001)	0.001* (0.000)	-0.002*** (0.000)	
Nb. competitors	0.018*** (0.001)	0.017*** (0.001)	0.017*** (0.001)	0.013*** (0.001)	
Constant	-1.660*** (0.216)	-1.031*** (0.211)	-0.441** (0.149)	0.486*** (0.028)	0.488*** (0.006)
Time fixed effect	Yes	Yes	Yes	Yes	Yes
<i>Outcome equation: re-election</i>					
Shock	-0.181*** (0.017)	-0.199*** (0.017)	-0.212*** (0.016)	-0.159*** (0.014)	-0.150*** (0.013)
NHPP	-0.256*** (0.022)	-0.268*** (0.022)	-0.281*** (0.021)	-0.270*** (0.019)	-0.278*** (0.017)
Inv. Expenditure	0.048*** (0.010)				
Debt	-0.074*** (0.006)				
EPCI (Integrated)	-0.200*** (0.021)	-0.212*** (0.021)			
EPCI (Isolated)	-0.039 (0.091)	-0.029 (0.091)			
Median Income	-0.051* (0.021)	-0.050* (0.020)			
Inc. gender	0.145*** (0.022)	0.137*** (0.022)	0.112*** (0.021)		
Inc. age	0.033*** (0.001)	0.033*** (0.001)	0.031*** (0.001)		
Vote share for president	-0.002** (0.001)	-0.003*** (0.001)	-0.003*** (0.001)	-0.004*** (0.001)	
Constant	0.329 (0.245)	0.206 (0.228)	-0.167* (0.079)	1.595*** (0.034)	1.086*** (0.032)
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	56992	56992	61881	70876	92114
Log Likelihood	-40136.33	-40387.5	-43146.89	-56451.77	-73911.37
ρ	-0.581 (0.076)	-0.587 (0.074)	-0.719 (0.066)	-0.519 (0.040)	0.310 (0.039)

Notes: *p<0.05; **p<0.01; ***p<0.001 ; All control variables are listed in the table above. Heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level.

Appendix

Table C.12: Heckman Model - Occurrence of natural disaster during the electoral cycle: full table

	Pool		2020		2014		2008	
<i>Selection equation: candidate (0 or 1)</i>								
Shock	-0.008 (0.013)	-0.022 (0.014)	-0.013 (0.017)	-0.013 (0.018)	-0.005 (0.028)	-0.021 (0.033)	-0.021 (0.038)	-0.037 (0.042)
NHPP	-0.030 (0.018)	-0.072** (0.025)	-0.040 (0.025)	-0.039 (0.035)	0.023 (0.034)	-0.012 (0.049)	0.017 (0.050)	-0.032 (0.069)
Shock × NHPP		0.087* (0.036)		-0.002 (0.049)		0.057 (0.071)		0.104 (0.099)
Inv. Expenditure	0.101*** (0.007)	0.101*** (0.007)	0.090*** (0.009)	0.090*** (0.009)	0.109*** (0.017)	0.114*** (0.018)	0.133*** (0.020)	0.133*** (0.020)
Debt	-0.015*** (0.004)	-0.015*** (0.004)	0.002 (0.005)	0.002 (0.005)	-0.021* (0.010)	-0.022* (0.010)	-0.003 (0.010)	-0.003 (0.010)
EPCI (Integrated)	-0.014 (0.016)	-0.014 (0.016)	-0.011 (0.019)	-0.011 (0.019)	0.009 (0.031)	0.006 (0.032)	0.137** (0.051)	0.137** (0.051)
EPCI (Isolated)	-0.076 (0.064)	-0.076 (0.064)			0.491 (0.306)	0.513 (0.299)	0.024 (0.069)	0.024 (0.069)
Median income	0.006 (0.013)	0.007 (0.013)	-0.011 (0.014)	-0.011 (0.014)	-0.118 (0.109)	-0.164 (0.111)	-0.058 (0.101)	-0.059 (0.101)
Inc. gender (M)	0.267*** (0.016)	0.267*** (0.016)	0.276*** (0.021)	0.276*** (0.021)	0.297*** (0.036)	0.317*** (0.038)	0.306*** (0.053)	0.307*** (0.053)
Inc. age	0.010 (0.005)	0.010 (0.005)	0.007 (0.007)	0.007 (0.007)	-0.015 (0.012)	0.001 (0.013)	0.018 (0.016)	0.018 (0.016)
Inc. age2	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000* (0.000)	0.000 (0.000)	0.000 (0.000)
Nb. competitors	0.019*** (0.001)	0.019*** (0.001)	-0.002 (0.001)	-0.002 (0.001)	0.217*** (0.004)	0.220*** (0.004)	-0.030*** (0.003)	-0.030*** (0.003)
Vote share for president	0.002*** (0.001)	0.002*** (0.001)	0.002* (0.001)	0.002* (0.001)	0.000 (0.001)	-0.000 (0.001)	0.003 (0.002)	0.003 (0.002)
Constant	-1.842*** (0.211)	-1.838*** (0.211)	-1.387*** (0.246)	-1.387*** (0.246)	-0.005 (1.180)	-0.058 (1.188)	-1.442 (1.069)	-1.418 (1.070)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Outcome equation: re-election (0 or 1)</i>								
Shock	-0.132*** (0.017)	-0.132*** (0.019)	-0.123*** (0.022)	-0.123*** (0.024)	-0.111*** (0.029)	-0.120*** (0.033)	-0.137** (0.047)	-0.125* (0.050)
NHPP	-0.121*** (0.023)	-0.122*** (0.032)	-0.106*** (0.032)	-0.107* (0.046)	-0.159*** (0.034)	-0.177*** (0.050)	0.017 (0.058)	0.061 (0.086)
Shock × NHPP		-0.001 (0.044)		0.002 (0.063)		0.017 (0.070)		-0.072 (0.117)
Inv. Expenditure	0.036*** (0.009)	0.036*** (0.009)	0.025 (0.013)	0.025 (0.013)	-0.003 (0.016)	0.003 (0.016)	0.165*** (0.024)	0.165*** (0.024)
Debt	-0.068*** (0.006)	-0.068*** (0.006)	-0.035*** (0.007)	-0.035*** (0.007)	-0.158*** (0.014)	-0.162*** (0.015)	-0.026 (0.014)	-0.026 (0.014)
EPCI (Integrated)	-0.231*** (0.020)	-0.231*** (0.020)	-0.091*** (0.024)	-0.091*** (0.024)	-0.410*** (0.030)	-0.419*** (0.032)	0.008 (0.061)	0.008 (0.061)
EPCI (Isolated)	-0.050 (0.087)	-0.051 (0.087)			-0.895*** (0.192)	-0.878*** (0.192)	0.037 (0.084)	0.039 (0.084)
Median income	-0.052* (0.020)	-0.052* (0.020)	-0.025 (0.019)	-0.025 (0.019)	-0.620*** (0.107)	-0.683*** (0.109)	0.090 (0.123)	0.093 (0.123)
Inc. gender (M)	0.158*** (0.022)	0.158*** (0.022)	0.187*** (0.032)	0.187*** (0.032)	0.017 (0.038)	0.041 (0.039)	0.351*** (0.065)	0.350*** (0.065)
Inc. age	0.027*** (0.001)	0.027*** (0.001)	0.023*** (0.001)	0.023*** (0.001)	0.029*** (0.001)	0.031*** (0.002)	0.050*** (0.003)	0.050*** (0.003)
Vote share for president	-0.002** (0.001)	-0.002** (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.010*** (0.001)	-0.010*** (0.001)	0.003 (0.002)	0.003 (0.002)
Constant	0.717** (0.225)	0.719** (0.225)	0.372 (0.234)	0.372 (0.235)	7.662*** (1.096)	8.188*** (1.114)	-4.651*** (1.197)	-4.694*** (1.201)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	54956	54956	27742	27742	21421	21421	5793	5793
Log Likelihood	-38540.99	-38537.81	-21730.48	-21730.48	-9583.302	-9575.287	-4820.489	-4818.918
ρ	-0.80 (0.101)	-0.80 (0.101)	-0.95 (0.178)	-0.94 (0.178)	-0.99 (0.0001)	-0.83 (0.027)	0.90 (0.040)	0.89 (0.040)

Notes: *p<0.05; **p<0.01; ***p<0.001 ; All control variables are listed in the table above. Heteroskedasticity-consistent standard errors in parentheses, clustered at the municipal level.

Conclusion

Local governments are significantly affected by the occurrence of natural disasters. Municipalities are the closest local government to citizens as such, they are best placed to respond to their needs, but they are also directly affected by the crisis. A natural disaster is indeed a significant challenge for a municipality because, beyond making a population vulnerable, it will incur a certain cost for the government. This cost will be of various kinds. First, there is a direct cost related to the damages caused by the disaster, including repair, reconstruction, and the continuity of public services in a crisis situation. Additionally, there are expenses associated with preemptive measures against natural disasters, which may be implemented prior to the occurrence of an initial disaster. However, these expenditures often serve to mitigate the impact of future shocks. Finally, there are indirect costs for the municipality and especially for the mayor, who will have to assume this major event and its decisions in front of voters and sometimes even in a court of law.

The first two chapters of this thesis focus on the direct costs, i.e., the budgetary reactions of municipalities following a natural disaster. The objective was, first in Chapter 1, to empirically observe the effects of a natural disaster on various budgetary aggregates of French municipalities. In the second chapter, the same objective is approached from a theoretical perspective to understand the dynamic relationships between accounts. Finally, the third chapter concentrates on the prevention of natural risks. Initially, it assesses the effectiveness of prevention plans to mitigate the effects of a disaster, and secondly, it aims to observe the indirect costs that have repercussions on mayors in electoral situations.

The first chapter examines the impact of natural disasters on municipal budget accounts in France. To achieve this, I employ two dynamic methodologies to estimate how local governments respond to major catastrophic events. The first method is a difference-in-difference approach with multiple time periods. This method enables the identification of the causal impact of natural disasters on a municipality's budget, taking into consideration the sporadic occurrence of these events. However, while this methodology accounts for the staggered effect of the treatment, it analyzes accounts individually and may overlook the endogeneity between municipal

accounts. To address this issue, I use a Panel Vector Autoregressive model, inspired by the macroeconomics literature on natural shocks. This method considers the endogeneity of the main municipal accounts using a vector of outcome variables. I find that municipal expenditures, revenues, and grants significantly increase immediately after a natural disaster, with this effect seemingly persisting for 2 to 6 years after the shock. Moreover, I estimate the impact on municipal sub-accounts to understand the nature of expenditures or revenues involved. I find that the capital expenditure sub-account is impacted, increasing after the disaster, along with noticeable increases in salary expenditure and current purchases. On the revenue side, there is an increase in investment grants in the two years following the disasters and then an increase in operating grants after 6 years. There is also an increase in local tax revenues after 5 years, indicating that the central government does not provide complete compensation for the damage caused by disasters, leading municipalities to raise taxes. Finally, I use an indicator of municipal financial health to categorize municipalities into three groups: (i) very good, (ii) good, and (iii) average or poor financial health. I find that natural disasters appear to have no significant effect on municipalities with very good financial health. However, as financial health declines, the effects of the shock become more pronounced. This analysis raises questions about the financial heterogeneity of municipalities and the role of financial health in their risk management, which I explore further in the second chapter.

The second chapter investigates the dynamic causal pathway of natural disaster shocks on local budget accounts. We construct and calibrate a model representing a municipality that could be affected by a natural disaster, resulting in the destruction of a portion of its capital stock. The municipality, acting as a benevolent decision-maker, seeks to maximize the welfare of its citizens based on the quantity of goods and public services. Public good production utilizes the stock of capital, which increases through investment, and the level of current expenditures. The financing of current expenditures, investments, and financial expenses is achieved through taxes, grants, and potentially debt accumulation. Within this general framework, we analyze two types of situations: municipalities with the ability to incur debt and municipalities with debt constraints. In the first scenario, the reduction in the capital stock is instantly compensated by an increase in investment financed by debt. In the second scenario, where the financial health of the municipality doesn't allow for debt, the augmentation of investment to counteract the natural disaster is funded by taxes and a reduction in current expenditures.

The last chapter examines prevention policies against natural disasters. Our study investigates, on one hand, whether prevention policies can effectively mitigate

the impact of natural disasters on municipal budgets. On the other hand, we explore the influence of the occurrence of natural disasters and the implementation of prevention policies on municipal electoral outcomes. Employing a staggered difference-in-difference methodology and a triple difference, we find that the impact of natural disasters on municipal budgets is significantly mitigated when natural hazard prevention policies are implemented at the municipal level. In contrast, municipalities without a pre-existing prevention plan before a shock occurs experience notable effects on their budget accounts. However, we observe that, while prevention policies can effectively mitigate the damage caused by natural shocks, the implementation of such policies has a negative effect on the probability of a mayor's re-election. To analyze the effect of natural disasters and prevention policies on re-election probabilities, we employ a Heckman model to address selection bias resulting from individual decisions by mayors to rerun for election. Our findings indicate that (i) the occurrence of natural disasters negatively affects re-election probabilities, and (ii) citizens disapprove of prevention plans. This supports the notion of "voters' myopia": voters may not perceive the short-term and long-term effects of prevention policies on local budgets, leading them to punish decision-makers for implementing these policies.

To conclude, this thesis provides new insights into the responses of local governments following a dramatic event. It is observed, initially, that municipalities affected by a disaster have an immediate reaction to address the consequences of the shock, particularly in terms of emergency, repair, and reconstruction expenditures, as well as to ensure the continuity of public services.

However, it is also observed that these expenses tend to remain elevated several years after a disaster. This indicates that municipalities struggle to recover from a shock, leading to persistent budgetary impacts.

Nevertheless, strategies for preventing natural risks have a positive effect on municipal budgets. From a public policy perspective, the implementation of natural risk prevention policies appears necessary at the municipal level. However, these findings do not take into account the heterogeneity of natural risk prevention plans.

Although risk prevention strategies seem effective, Chapter 3 demonstrates that elections do not incentivize mayors to implement such policies. Mayors are nonetheless held responsible in case of failure or errors in the management of natural disasters, particularly due to prevention policies. Thus, mayors face two contradictory effects: on one hand, they have a legal obligation to ensure safety in their municipality, and on the other hand, the implementation of prevention plans is not accepted by their constituents.

As highlighted in the Ministry of Environment's report on the perception of natural risks, the French are largely unaware of the risk of natural disasters. This

underscores both the lack of awareness of major climatic events and helps us understand citizens' reluctance towards public policies for risk prevention. The political challenge, therefore, is to inform citizens about the dangers of natural disasters so that local leaders can freely implement protective policies without risking electoral backlash. A better understanding of environmental and climate change risks seems necessary to encourage elected officials to develop risk management policies and thereby avoid direct budgetary impacts on local governments.

However, there is also a political dimension in the recognition of natural disasters. Indeed, the status of a natural disaster is subject to an interministerial commission, which decides whether or not to grant the status to a municipality. As described earlier, this procedure has been criticized for its lack of transparency. This raises questions about the political stakes behind this status, and whether the reform of the natural disaster regime has led to changes in the number and ways of granting this recognition. Where the recognition of natural disasters is both a significant financial issue for municipalities, mayors, and primarily for citizens benefiting from insurance, it is also a matter of political discourse and taking control of the issue of climate change and its consequences. Recognizing fewer natural disasters may be a way to limit the number of claims recorded. The change in the natural disaster regime after the 1999 storm had precisely this aim; the storm had been so costly that it was necessary to reduce the number of natural disasters recorded. A political decision behind this disaster reporting is an important limit that would be interesting to study more precisely.

Lastly, this thesis fits into and broadens our understanding of the various challenges posed by climate change, its causes, its consequences, and more generally the negative environmental externalities on local governments and citizens. Indeed, natural disasters are just a symptom of a more global phenomenon. Many issues are still to be explored regarding the repercussions of these environmental events on local governments, the provision of public services, healthcare delivery, or on citizens. Moreover, it also seems fundamental to focus on the causes of climate change, human actions, and their effects on populations and public policies. Specifically, questions surrounding air pollution emerge as critical issues for examination today to understand their consequences at the individual level, particularly regarding health, as well as political and public policy choices.