Institutional Drivers of Disaster Risk Reduction: A Comparative Study of Local Government Decisions and Outcomes in Chile

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Abstract

The focal point of the study is to identify institutional factors and processes that foster proactive local governments' interventions for Disaster Risk Reduction (DRR). The study proposes that a combination of municipal institutional conditions, linking social capital, and multilevel governance may have a profound effect on DRR outcomes in terms of prevention and critical infrastructure investments. In selecting cases to analyze these propositions, the research focused on representative Chilean municipalities subject to similar disaster risks, environmental deterioration, and climatic variability while exhibiting contrasting institutional contexts. The research employed comparative analysis of cases and complemented it with results from quantitative analyzes to explore the generalizability of the case study findings for a larger number of local government territories. The results show that municipal arrangements (internal organization and leadership) may influence the probability of local government efforts in DRR, but this effect depends on the existing linking social capital and multilevel governance relationships. The evidences suggest that the municipal institutional context and its links with governance actors at higher several of governance constitute the foundation for robust local DRR outcomes.

Keywords

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local governments, disaster risk reduction, multidimensional exploration

Introduction

This study explores the relationships between the incentives of national and regional policies, municipal commitments and interactions with society that may explain variations in decisions of local governments in DRR, in a developing country context. Specifically, the study explores relationships between municipal institutional arrangements, social participation, multilevel governance relationships, and decision-making processes of municipal governing councils regarding budgets and critical infrastructure investment initiatives, to compare and explain variations in DRR outcomes.

The first part of the study consists in an inductive analysis that compares three representative Chilean municipalities that have in common some characteristics with the collective majority (346). The analysis seeks to explain variations in local government decisions in terms of emergency expenditures and critical infrastructure investments. The evidences suggest that the characteristics of the municipal organization, institutional trajectories, leadership motivation, linking social capital (SC) in form of interactions between municipal councils and social organizations, and multilevel governance relationships (MLG) explain municipal decisions and outcomes in these cases. The second part explores the effects of identified factors in a larger number of municipalities (321). The review consisted of quantification of information of several sources and observation of correlations that provide information about the effects of the identified factors on local government decisions and outcomes. The results confirm the multidimensional character of the explanation of municipal responses.

Multilevel perspective: institutions, agents, linking social capital, multilevel governance

Because DRR at the local level arises from the interaction of geophysical, biophysical and institutional arrangements and depends on interactions, knowledge and attitudes toward risk (Alexander, 2000; Young, 2002; Ostrom, 2005; Adger et al, 2009), its possibilities and limits are likely to depend on the relationships between these various dimensions, the degree and quality of information and complementary collaboration.

Institutions consist of rules, structures and repeated behaviors with the ability to influence human decisions and outcomes (Powell and Dimaggio, 1991; Woolcok and Narayan, 2000). During the past two decades, scholars have made great strides in showing how municipal institutional dimensions may affect DRR by overcoming barriers, enabling change, and presenting opportunities to transform public policies into actions at the local level. Several institutional conditions to explain DRR have already been identified and systematized (e.g., Adu-Boateng, 2015; Anguelovski et al, 2014; Biesbroek et al, 2014; Burch, 2010; Crabbé, 2006; Portera et al, 2015; Rimboeck, 2013; Sapountzaki, 2011; Waters et al, 2014; Wen and Chang, 2015). In the natural hazard literature (e.g., Sapountzaki, 2012; Wen and Chang, 2015), losses differ across governments because of the effects of the quality of the institutions and institutional interactions. In climate-change adaptation and risk management literature (e.g., Adu-Boateng, 2015; Anguelovski et al, 2014; Burch, 2010; Crabbé and Robin, 2006; Rimboeck, 2013; Szlafsztein, 2015; Waters et al, 2014), institutions are path-dependent structures, regulations, and routines.

Agents involved in the institutions can interpret and influence their trajectories (Adger et al, 2009; Cashmore and Wejs, 2014). The DRR and climatic-change adaptation literature have highlighted the critical role of leadership for institutional change risk reduction, and adaptation. Adger et al (2009, pages 337–349) have stressed the subjective factors behind the decisions and courses of action of the agents. Comparing climate-adaptation planning approaches in the cities of Quito (Ecuador), Surat (India), and Durban (South Africa), Anguelovski et al (2014, page 165) underlined the critical role of political leadership in effective decision making and institutionalizing programs.

The linking SC literature offers also a well-established theoretical framework to explain variations in local government decisions (Adger, 2003; Ahn and Ostrom, 2008; Ostrom, 2005; Woolcock and Narayan, 2000). The SC concept refers to reiterated interpersonal relationships that can promote confidence and norms of reciprocity, and can better reach individual and collective objectives. Repeated interpersonal relationships have the capability of efficiently transmitting information and generating exchanges and coordination, and the potential to produce public benefits. Cross-scale interactions and the access to information and external actors in higher levels of political, economic or social hierarchy (Lin, 2008) increase the capacities of local groups to achieve their interests and goals and contribute to better local governance (Adger, 2003, pages 394–395; Woolcock and Narayan,2000).

The neo-institutionalist theories of polycentricity and multilevel governance (MLG)—relationships among multiple authorities with overlapping jurisdictions (Andersson and Ostrom, 2008; Hooghe and Marks, 2003; McGinnis, 1999; Ostrom, 2005; Young, 2002)—argue that the explanation of local governance variations requires consideration of the degrees and forms of nestedness of political actors within larger political systems. The MLG approach proposes that the information flows, coordination and support help the actors to craft and adjust their own behaviors over time and achieve effective results (Adger et al, 2005; Andersson and Ostrom, 2008; McGinnis, 1999; Ostrom, 2005). For this reason, the likelihood of desirable outcomes of DRR local governments' decisions may increase when municipalities are articulated and coordinated with other institutional levels of governance such as ministries, regional governments, social organizations, NGOs, private sector and science.

Chilean context: international and national background:

During the last three decades, the United Nations' system and the international regimes for environmental protection, disaster risk reduction and climate-change adaptation have fostered DRR at all scales (IPC, 2012, 2014; CRED, 2015; ECLAC, 2015; Mearns and Norton, 2010; O'Brien et al, 2006).

Chile (within 17°–56°S 66°–75°W) is located within the Pacific Ring of Fire, which exposes it to frequent earthquakes, tsunamis and volcanic eruptions, and it is particularly affected by Pacific Ocean influences (El Niño and La Niña) and climate change (ECLAC, 2015). In the World Risk Index (Alliance Development Works, 2015), the country ranks was 19 in 2013 and 256 in 2015. As illustrations, severe drought affecting central and south Chile in 2008 caused emergencies in 50 municipalities, and the government expended about US$30.5 million, delivering only bales of forage and water for human consumption (Ministry of Agriculture, 2014); the Chilean earthquake and tsunami on 27 February 2010, affected 2.7 million victims and caused a total of US$30 billion in reported damages—18% of Chilean GDP and 24.2% of the global reported damages for that year (CRED 2011, page 2).

In the last three decades, evidence of severe environmental degradation and increasing awareness of risk exposition led to a greater emphasis on environmental protection and disaster prevention by successive Chilean governments through environmental framework laws (1994, 2010), new Ministries of Environment and Energy (2010), and an environmental impact assessment system, planning and information instruments and land-use planning and national climate-change action plans, among others (Ministry of Environment, 2011). Converging with international standards, the government modernized its national emergency system through Decree No. 156, 12 March 2002, and reinforced the system as consequence of the 2010 earthquake (ONEMI, 2014).

Chilean municipalities have the potential to lead DRR at the local level through their critical functions for the economic, social, environmental protection, land-use planning, utility provision, critical infrastructures (e.g., water, transport, waste management), and risk prevention, among others (Constitutional Municipal Law 18.695). International and national policies should be reflected in favorable municipal decisions to foster DRR, as shown in Fig. 1

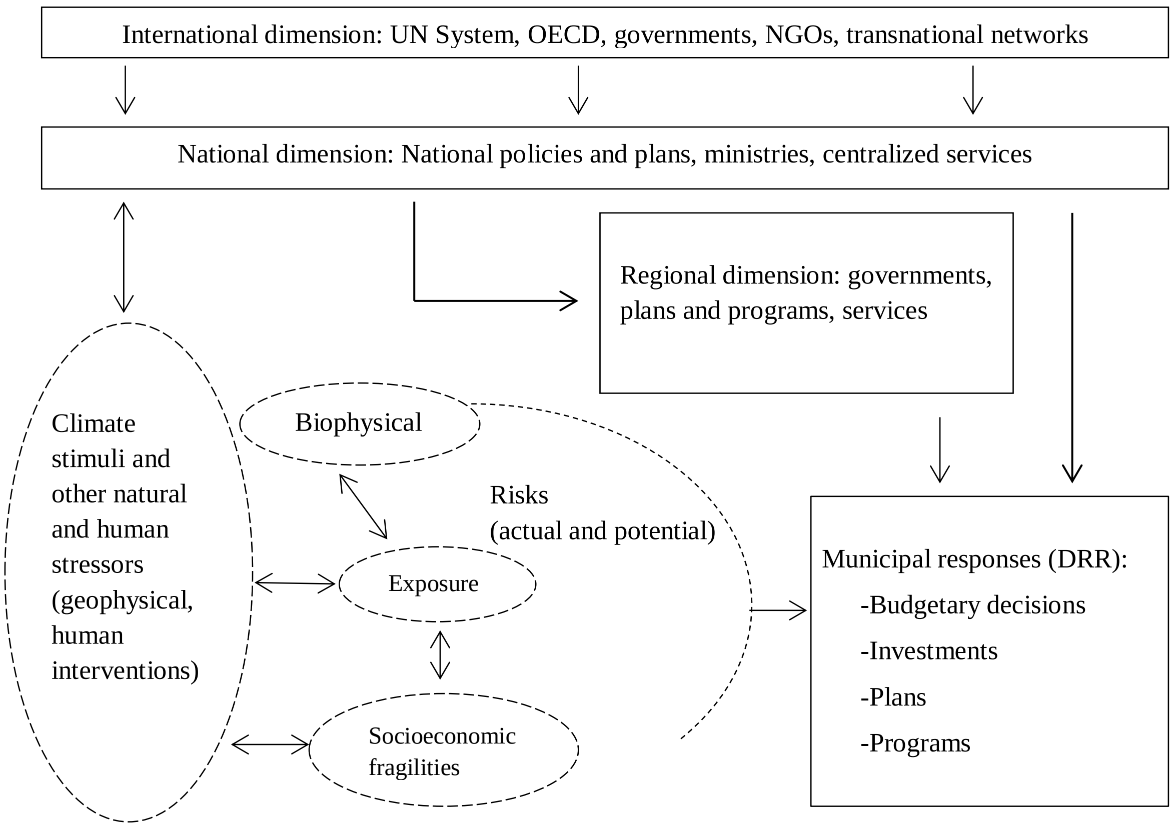

Fig. 1. Schema of multilevel input at municipal level (arrows represent relationships)

Comparative qualitative analysis

Strategy and data

Supported by previous research (Valdivieso, 2016), the first step of analysis begins with the comparison of three representative Chilean municipalities—Cauquenes, Lebu and Panguipulli (Fig. 2)—selected because they have both contrasting and similar features. They are located in three geographical settings characteristic of Chile: valley, coastline and mountains. Their political, administrative and budgetary structures are similar to each other, and they have limited financial capacity and few human resources to fulfill their functions (SIMIM, 2019). All three are natural resource–dependent, affected by overexploitation of natural resources, with socioeconomic fragilities and exposed to climate change and other environmental risks. Like most Chilean municipalities, they have been affected by extreme climatic and geophysical events in the last 50 years, such as the earthquake of 2010, and frequent droughts, forest fires, and floods during the last decade (CONAF, 2019; DESINVENTAR, 2019). Otherwise, they follow different paths with regard to DRR: Cauquenes and Lebu lack policies and plans for environment protection and DDR, and are not well prepared to deal with extreme events (Forttes, 2014; UNDP, 2011; Valdivieso, 2016); Panguipulli features a higher degree of preparedness for disaster risk reduction and has plans, regulations and more critical infrastructure investments (Amsteins, 2013; Municipality of Panguipulli, 2005, 2010, 2012a, 2013a; Valdivieso, 2016).

Source: Google Earth 2019

Fig. 2. Selected municipalities in south-central Chile.

The period 2009–2014 favored the availability of registries and documents for research. The research was built around two data-collection methods: semi-structured interviews with municipal workers (12 total), heads of households (120) and social directors (13) and official documentation such as legal and regulatory, municipal and national statistics, investment initiatives, municipal documentation and annual public reports. To compare municipal councils, 2014 was selected for systematic review of their meeting minutes, documenting the relationships between mayors and councilors, enforcement of regulations, work routines, budget and investment decisions and relationships with municipal and external actors.

Risks, socioeconomic fragility

The three municipalities are exposed to environmental risks and extreme events: earthquakes in all three locations, flooding by large waves in Lebu (coastline), volcanic eruptions in Panguipulli (mountain) and severe heat waves in Cauquenes (valley). Periodically, they confront emergency situations caused by extreme events (droughts and water deficiencies, forest fires, snowstorms, flooding), and between 1971 and 2011, each municipality was affected by an average of 24 extreme events (CONAF, 2019; DESINVENTAR, 2019).

On the other hand, socioeconomic fragilities predispose everyone to negative effects of climate change and other environmental problems. A significant percent (60%) of the interviewed heads of households perceived the conditions in which they live as fragile and vulnerable: inadequate housing, deficiencies in sanitary infrastructure, few job opportunities, income uncertainty and weak health systems. In the urban zones, the heads of household associated the poor states of housing and roadway infrastructure to the concept of exposition, and in rural zones, they attributed it to difficult access to water resources, lack of sewage systems, poor state of roadways, labor instability, lack of health services and isolation.

Local government decisions in DRR

The interviewed municipal workers spoke of the risk management concepts and disaster administration for DRR budget and critical infrastructure investments, reporting that the municipal councils make decisions about these topics.

During the period 2009-2014, Panguipulli's municipal council spent more sessions and more time dealing with problems and initiatives related to DDR[2], in average : 28 sessions compared to 12 in Lebu and 7 in Cauquenes. The municipalities budgeted funds for preventing emergency situations (SINIM, 2019). The initial budget decisions considered the risks of extreme events beforehand, while actual expenditures represented the decisions that were made during an event. The differences between the initial and actual budgets are interpreted as a lack of preparation. Upon comparison from 2008 to 2014, Panguipulli was better prepared to confront emergency situations (Valdivieso, 2016).

During 2009–2011, Panguipulli allocated 12% of municipal investments to critical infrastructure investments for risk reduction, Lebu 2.7% and Cauquenes 0.3% (Municipality of Cauquenes, 2015; Municipality of Lebu, 2012b, 2013, 2014, 2015a; Municipality of Panguipulli, 2012b, 2013b, 2014, 2015; Valdivieso, 2016). For example, Panguipulli invested in 10 environmental protection and risk reduction projects (topographic, soil and hydrogeological studies, solid waste, composting facilities, treatment of city water, regulations for lake activities, monitoring system for environmental sustainability, infrastructure for firefighters and social housing). Lebu invested in four (solid waste collection, ethics signs, machinery to rescue boats, and repositioning the firefighting department). Cauquenes invested in one (firefighting department). Panguipulli applied to the National Investment System for two studies - water reserves at various locations and closing the municipal well- and Lebu applied for four projects -repositioning one firefighter company, evacuation routes, two high-altitude public squares-. The evacuation route and public square projects were designed by the

[2] Source: Municipal council meeting minutes provided by the secretaries of the municipalities.

regional government after the tsunami of 2010 (Ministry of Housing and Urban Planning, 2015).

Explanatory institutional factors

Internal regulations, electoral outcomes, and council autonomy

The internal regulations combined with electoral results affected the balances of power in the councils of the three local governments, strengthening the position of the mayors supported by a large majority.

In Cauquenes and Lebu, the municipal regulations gave broad authority to the mayors to run the municipalities and council sessions, and control information flow (times in minutes for interventions in the council, agenda topics, study commissions, access to municipal offices, agreements and procedures for voting, sanctions, hearings with external actors, etc.). In Panguipulli, there were no restrictions on interactions with external actors; councilors could autonomously form study commissions, integrate workers into them, request records considered necessary for their work and send reports to the council. In the election of year 2012, the candidates who became mayors in Cauquenes and Lebu had an absolute majority (55% and 58.6%, respectively), the same as the candidates for council supporting them (data available at www.servel.cl). In Panguipulli, the candidate who became mayor did not obtain the majority of votes and more than half of the councilors do not belong to his political coalition. Therefore, the balance of power in the council may incentivize competition, favor social participation channels, and affect DRR local government decisions.

Power balances manifest in routines and interactions. In Cauquenes and Lebu, mayors and administrative workers provided information about topics and held votes on initiatives under municipal authority, and the role of the council consisted of commenting and unanimously approving initiatives. In Panguipulli, the mayor as well as councilors proposed initiatives, looked at proposals, deliberated, made fieldwork, and entered citizen concerns into the discussion. For example, from an average of 127 topics related to DDR and socioeconomic fragilities reduction submitted to the councils in 2014, Cauquenes and Lebu councilors intervened 17 times, formulating questions and comments, and approving all of the initiatives proposed by the mayor. In Panguipulli, the councilors intervened 59 times, presenting initiatives, providing information and vetoing some of the mayor's initiatives.

Municipal organization

Regarding municipal structure and personnel, Cauquenes' and Lebu's environmental offices were located in departments without specialized personnel to deal with environmental risks, therefore, were not able to generate information to provide feedback on the risk reduction policies of the municipality. In Panguipulli, the Secretary of Municipal Planning (SECPLA) had a Department of Territorial and Environmental Planning that advised the council with reports about the infrastructures and environmental situation in the municipality, water resources, and submission of DRR projects, all supported by specialized professionals and an external consultant. The department's emergency office carried out its risk prevention activities in coordination with other offices, and active technical committees coordinated the activities in the different offices and departments (planning, project analyses, review of administrative procedures, evaluation of goal achievement). In Cauquenes and Lebu, respectively, only 18.9% and 27.94% of the contracted workers had professional or academic degrees; in Panguipulli, 33.1% have them. In their environment departments, Lebu had one worker with a degree and Panguipulli had seven professionals with environmental engineering degrees and undergraduate degrees in biological sciences. Additionally, Panguipulli's council introduced institutional goals for EMDR personnel in their performance agreements in 2014.

The organizational structures and staff characteristics affected work routines, performance, and interactions between municipal workers and local government (municipal council), where DDR decisions were made. Assessments of Cauquenes' and Lebu's municipal development plans (PLADECO) identified challenges regarding the verticality of their structures, offices and departments working in isolation and coordination problems (Municipality of Cauquenes 2010, pages 131–132; Municipality of Lebu 2012a, page 126).

Additionally, differences in transparency practices of these municipalities also affected routines, relationships with external agents, decisions and outcomes. During 2009–2014, Panguipulli made significant strides to improve municipal procedures and information services toward achieving national standards of transparency (Valdivieso and Bernas, 2014; Valdivieso, 2016), and the results manifested in increasing compliance with national legal standards of transparency. In contrast, Cauquenes and Lebu were tighter municipalities with less access to municipal information, as reflected in their institutional websites. Between 2009 and 2014, 3 of 36 audit reports from the Regional Comptroller General's Office on alleged irregularities in budgetary procedures, management and compliance with laws in Cauquenes referred to transferred funds out of emergency and social programs budgets (Comptroller General of the Republic, 2019).

Leadership, motivation, and institutional change

Beyond the observed municipal institutional arrangements of Panguipulli was the action of one policy entrepreneur for institutional change during the decade of 2000. Motivated by his leftist political vision and the experience of living in exile in Germany (1973–1985), where he had become familiar with risk reduction and sustainable endogenous development perspectives. During his management (2000–2008), A. Kohler prioritized DRR, development, tourism and reforms in the municipal structures[3], such as new municipal regulations (2004, 2005), creation of Territorial and Environmental Planning in SECPLA, hiring 30 young professionals into various departments, new methods to strengthen coordination and Local Agenda 21 in municipal planning (Municipality of Panguipulli, 2005; Valdivieso, 2016). The municipality formed alliances and collaboration agreements with diverse actors in the academic, private and public worlds and fostered entrepreneurship in sustainable tourism. The political change during Kohler's mandate was an important factor for the improvement of local governance decisions regarding DRR in Panguipulli; the reforms had clear effects on municipal commitments, the institutionalization of an agenda of DRR and endogenous development.

During the period 2008-2016, the center-right mayor of Panguipulli was also motivated and prioritized DRR in the municipal agenda (El Diario de Panguipulli, 2015; Municipality of Panguipulli 2013a, 2013b, 2014, 2015; Valdivia Capital, 2015; Wordpress, 2015), and the municipal institutional arrangements (internal regulations, municipal council autonomy, internal organizations) favored the circulation of information and knowledge on topics of DRR. The combination of mayoral priorities, a proactive role of councilors and municipal organization correlated with increasing relationships and interactions between the council and actors of other governance levels

[3] Former Mayor Kohler accepted the invitation to participate in this research as an interviewee, authorizing that he be cited as a source of information.

in DRR issues (social organizations, NGOs, regional government, ministries). The reciprocal bidirectional and multidirectional relationships between the council and external actors correlated with frequent interactions with civil social organizations (territorial and NGO). The synergistic relationship between the council and external actors transmitted information, produced learning and enriched both the local governance and decisions and actions in DRR.

Contrasting, in Cauquenes and Lebu, the mayors prioritized economic growth and municipal modernization, and DRR was not a priority. The center-right major of Cauquenes invested time and resources in interactions with different actors and organizations to achieve these goals (La Prensa, 2015; Municipality of Cauquenes, 2015). The municipal institutional arrangements (internal regulations, operational rules and rules in use) favored his control of both the council and the municipal departments. The municipal organization did not have the possibility to facilitate information flows and knowledges about DRR in the local government agenda due to lack of personal. Bidirectional or supportive relationships between mayor and external organizations consisted in exchange for electoral support and other benefits, but not to addressee DRR issues. As in Cauquenes, the center-left major of Lebu was motivated with the modernization of municipal structures and economic growth (Municipality of Lebu, 2013, 2014, 2015a; Radio Biobio, 2015), the municipal institutional arrangements favored his control of the municipal agenda, and council relations were oriented towards the municipal bureaucratic structure, which made the final municipal decisions according with the priorities of the major. The municipal organization did not facilitate circulation of information and knowledge about DRR, except during disaster situations (e.g., 2010). The relationships with social organizations comprised applications for specific benefits related with the agenda of the major.

Linking social capital and multilevel governance

Municipal residents who participated in territorial social organizations had individual and collective goals to reach, such as social subsidies and improving sanitation, housing and critical infrastructures. These organizations incentivized participation because enrollment in the municipal registries offered the possibility of engaging with the municipality, applying for various benefits, communicating their needs and being informed about other opportunities.

For 2009–2014, the average rates of enrollment in legally registered territorial organizations for every 1,000 inhabitants in Cauquenes, Lebu and Panguipulli were 11.7%, 12.6% and 21.7%, respectively (Valdivieso, 2016). Given that the organizations enrolled in the municipal registries to interact with the local governments and other public services, Panguipulli had the most potential for development of linking social capital and multilevel governance.

Civil society organizations had the ability to interact with municipal councils regarding DRR issues though correspondence, public hearings and community initiatives. The interactions were support exchanges (bi and multidirectional) when the council made a decision and responded, supporting or promising municipal resources and when interacted with a third party, for example, requiring the intervention of another institution. The mayor and the councilors announced themselves, shared opinions about a topic, offered evidence and in some cases deliberated, discussed and made a decision. The quantification of relations showed differences among the three municipalities (Table 1).

Table 1

Relationships between municipal councils and social organizations (2014)

	Away	Toward	Bidirectional	Multidirectional	Total
Cauquenes					
Community organizations	-	11	2	4	17
Non-government organizations	-	2	-	-	2
Lebu					
Community organizations	1	3	5	3	12
Non-government organizations	1	-	2	-	3
Panguipulli					
Community organizations	1	18	13	15	47
Non-government organizations	-	3	8	6	17

Sources: Minutes of Cauquenes' municipal council provided by municipal secretaries of Cauquenes, Lebu, and Panguipulli.

These relationships are correlated with differences in multilevel governance relationships. Fig. 7 provides information about relations between the councils and several external actors.

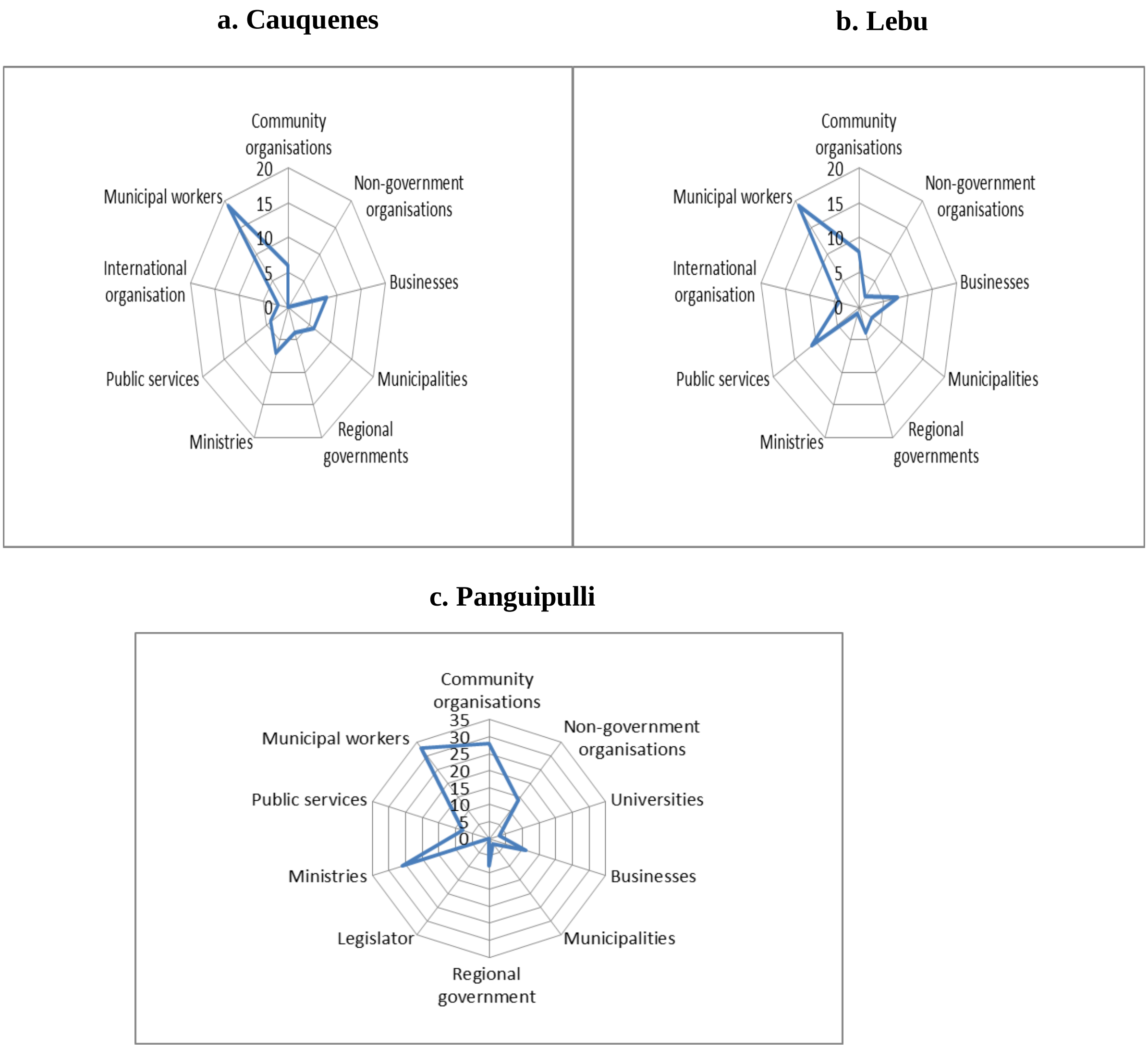

Fig. 7. Relations of municipal councils. The center of each graphic represents the council; numbers represent quantity of bidirectional and multidirectional relations with external actors and municipal offices; dark blue lines represent the shapes of bidirectional and multidirectional relations. *Sources:*Minutes of the municipal councils provided by municipal secretaries.

In Cauquenes and Lebu, the social organizations' relationships with councils consisted of written requests to obtain benefits and information, and the matters were sent to be resolved by various municipal offices (Valdivieso, 2016). In 10 instances of public hearings in Panguipulli, social organizations reported community initiatives for infrastructures to manage water resources, improve roadways, community recycling, maintain and clean public spaces and provide living and sanitary solutions, declaring their objectives to improve quality of life, confront environmental problems, and prevent risk situations. The initiatives were integrated into offerings of municipal critical investment initiatives and interactions with other organizations of the governance. The pressure from the organizations incentivized the elaboration of reports about infrastructures, contamination and water resources, and contacting public services and ministries to request support and action. In four cases, their interventions made way for the review of plans, programs and policies on solid waste management, composting and conditions for facing emergencies, broad public campaigns to encourage joint responsibility among neighbors in maintaining infrastructures and public spaces, and environmental certification for the municipality. Fig. 5 compares quantifications of these contributions.

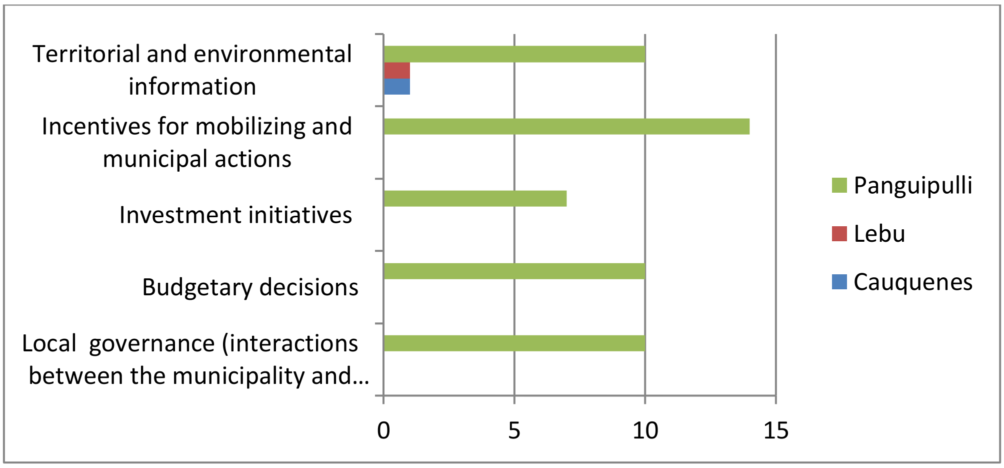

Fig. 5. Social organizations and DRR. *Source:* Municipal council minutes (2014). Bars represent the quantification of social organizations interventions in the council

Some interventions of non-government organizations made way for studies and actions by the council for infrastructures and services to control contamination sources and protect forests (Fig. 6). Examples include analysis of photographs showing forests and water resources, studies and analyses of contaminating factors, topography, soil, use of the shoreline, revisions to the water code, protections for the water.

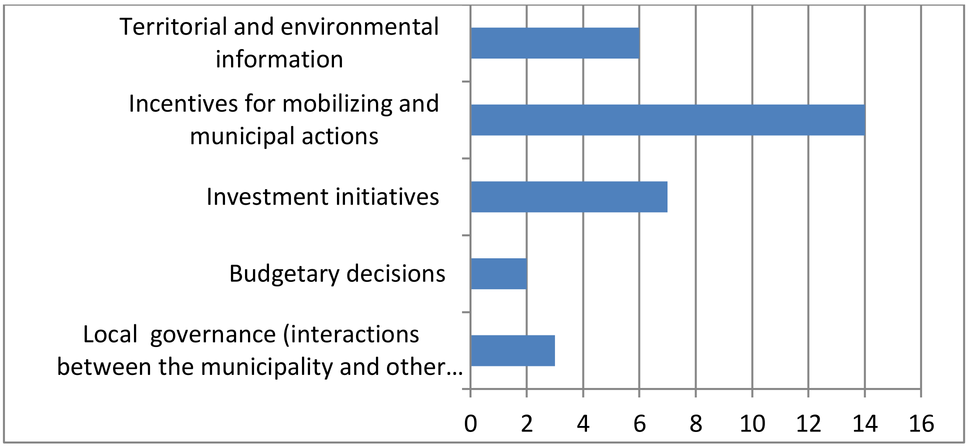

Fig. 6. NGOs and DRR in Panguipulli. *Source:* Municipal council minutes. Bars represent the quantification of social organisations' interventions in the council.

Remarks: municipal commitments, linking social capital and multilevel governance

The inductive comparative analysis shows the importance of specific institutional arrangements for DRR, related to institutional trajectories, internal regulations, and representation in the councils, municipal organizational structures, capacities, and routines and the relationships between decision makers and social organizations. These dimensions had consequences on how local governments made decisions.

The experience of Panguipulli suggests that the combination of municipal institutional arrangements, linking social capital, and multilevel governance relationships may have positive effects on DRR. The concerns and social information channeled through social organizations enriched the discussions and learning processes of the municipal council, and motivated initiatives, interactions, decisions, and concrete actions that improved DRR. The local knowledge represented a substantial contribution to comprehensive DRR and enriched the MLG relationships.

Quantitative exploration

Framework

From the inductive perspective of the case study analysis, we recognize that DRR among Chilean municipalities is the result of municipal councils' decisions under certain municipal contextual conditions and institutional arrangements, given the incentive structures and utility functions.

Each local government works with a particular set of contextual characteristics, X, that recognizes the heterogeneous costs and benefits derived from investments in DRR. For example, the geographical location or the experience of having been affected by extreme events increases the perception of risks of potential damage, influencing the expectation of benefits from DRR investment. In addition, institutional factors such as national policies and MLG dynamics, availability of internal regulations, organizational structure, personnel and institutional trajectory, leadership and ideological vision influence the balance of costs and benefits, being revealed, for example, in the routines that characterized council meetings when councilors addressed topics of communal politics and made decisions in the three case study municipalities. On the other hand, linking social capital (SC) in terms of social participation and synergistic relationships between social organizations and the municipality have the potential to positively influence municipal decisions in DDR. Figure 8 illustrated the process.

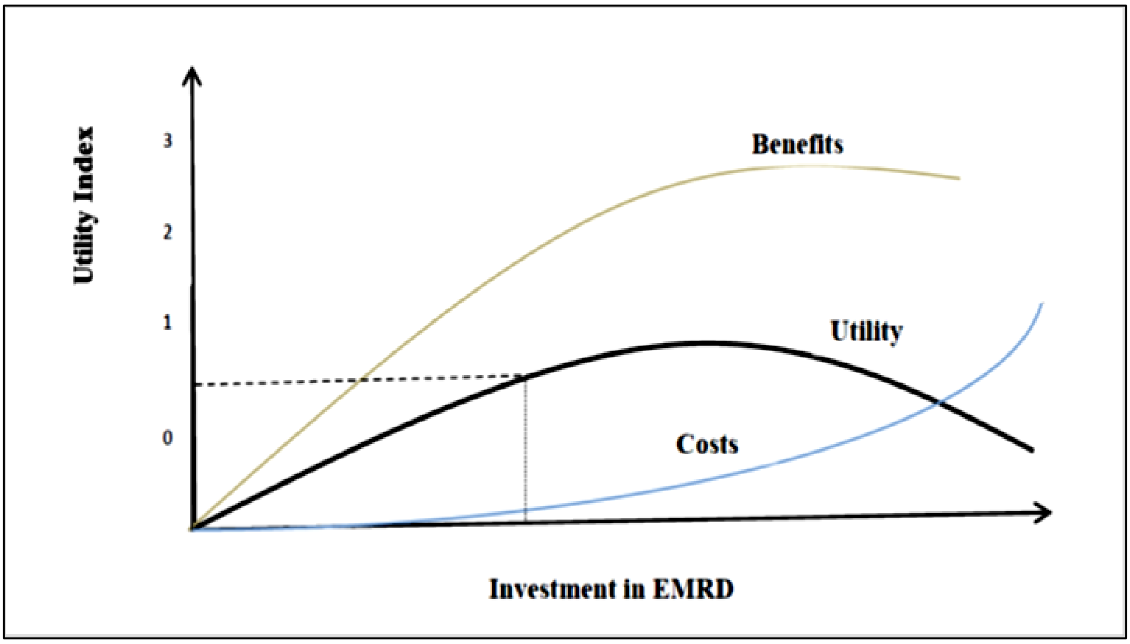

Fig. 8. Determination of optimal investment in EMDR

In Figure 8, the benefits of DDR investment is represented with a growing, continuous and concave function and the costs with a convex function[4].

Under these assumptions, a municipality i at time t chooses an optimal level of investment Y_{it} that is explained by a linear index of a vector of municipal characteristics X_{it}, including institutional arrangements, linking SC, MLG interactions, municipality-specific time-invariant characteristics β_i , and an idiosyncratic random component ε_{it}:

$$Y_{it} = \sum_{k=1}^{K} \alpha_k X_{kit} + \beta_i + \varepsilon_{it} = X_{it}\alpha + \beta_i + \varepsilon_{it}$$

Time-invariant characteristics, when observed or not, are subsumed into the individual effect β_i, allowing to control for both observable and unobservable time-

[4] Benefits are subject to diminishing returns: investments made when there is severe scarcity tend to generate large improvements in terms of adaption or vulnerability reduction. As more needs are covered, the additional or marginal resources tend to generate much less substantial gains in these regards. Cost convexity is also a common feature under budgetary constraints because decision makers sacrifice increasingly important alternative uses for these resources as investment increases.

invariant municipality characteristics. This makes panel-data estimators particularly robust to omitted variable and/or endogeneity problems.

For analytical effects and with the purpose of examining the capacity for making generalizations and implications from this approach, we explore quantitative data from a large number of Chilean municipalities.

Variables and data

Selecting Chilean municipalities with variations local government decisions and outcomes in DRR, we are able to explore the assumptions on potential effects of the identified institutional arrangements, linking social capital (SC) and multilevel governance (MLG) relationships on local government DRR decisions.

Considering the Chilean context, we use three indicators for municipal decisions as dependent variables, each reflecting a different aspect of the same latent variable DRR (Table 2). "Budget items for emergency funds - log(emerg funds m$/hab)"[5] for the years 2009–2014 is a ratio variable indicating annual amount of budgetary resources. Our sources were the annual municipal budgets provided by the municipalities.

"Critical Infrastructure for Adaptation[6] - log(inv adapt/hab)" and "Critical Infrastructure for Vulnerability Reduction - log(inv vulner/hab)"[7] investments for the period 2009–2014 including both environment protection and mitigation[8] indicate the costs of municipal projects entered in the National Investment System each year. The source for investment is the Integrated Projects Bank of the Ministry of Social

[5] Municipalities use emergency funds for the organization and management of resources and responsibilities for addressing all aspects of emergencies and disasters, in particular preparedness, response and initial recovery steps (UNISDR, 2015).
[6] Critical infrastructure and adaptation investments for adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects (IPCC, 2012).
[7] Critical investments for reduction of the circumstances of a system that make it susceptible to the damaging effects of a hazard.
[8] Initiatives that limit, stop or reverse adverse impacts of hazards and related disasters, and the magnitude and/or rate of long-term processes (UNISDR, 2015).

Development (Ministry of Social Development, 2019). We consider the expression of these variables as the cost divided by the population of the municipality for a given year.

Table 2. Description of variables

Variables	Description
Dependent variables	
log(emerg funds m$/hab)	Emergency funds divided by citizens
log(inv adapt/hab)	Costs of adaptation investment initiatives divided by citizens
log(inv vulner/hab)	Costs of vulnerability investment initiatives divided by citizens
Independent variables	
log(SUBDERE neighb transf/hab	SUBDERE transfers for investment in neighborhood improvement
log(SUBDERE manag transf/hab)	SUBDERE transfers to strengthen municipal management
log(MININT local transfer/hab)	Transfers of Subsecretary Ministry of Interior for safety, risk management and emergencies
log(MINAGRI local transf/hab)	Transfers of Ministry of Agriculture for adaptation, mitigation and emergencies
log(MMA local transfer/hab)	Transfers of Ministry of Environment for environmental certification
log(curr reg transf/hab)	Transfer of regional governments for local development
mun council autonomy index	Index of council autonomy regarding mayor
mun org index	Index of flexibility and coordination in the municipal structure
mayor affinity in mun council	Index of concentration of votes of councilors close to the mayor
transpar goal	Position in national ranking of municipal transparency
envir contract rate	Percentage of staff for environmental activities
emerg contract rate	Percentage of staff for emergencies
Centre-right mayor	Mayor affiliation to a center-right party (Independent category omitted)
Centre-left mayor	Mayor affiliation to a left-right party (Independent category omitted)
Social participation	Social participation rate
community org rate	Registered social organizations per thousand inhabitants
Context variables	
log(rain mm)	Rainfall, Annual precipitation (millimeters)
Mercalli X post 2010 earthqk	Mercalli magnitude of the 2010 earthquake
Mercalli X years after 2010 earthqk	Effects of earthquake over time
log(num extr event)	Number of extreme events between 1971 and 2011
log(cost extr event)	Estimated total cost of extreme events during 1971–2011
population density	Population divided by surface
poverty rate	Population in poverty and extreme poverty
urban rate	Urban population
coast	Location on the coastline (mountain category omitted)
Valley	Location in the valley (mountain category omitted)

Notes: hab, inhabitant; SUBDERE, Undersecretary of Regional and Administrative Development; MININT, Ministry of the Interior; MINAGRI, Ministry of Agriculture; MMA, Ministry of Environment.

The explanatory variables are grouped into four categories: MLG, municipal arrangements, ideology and linking SC variables. As for governance multiscale interactions, we are interested in six financial transfers (ratio variables) from ministries and regional governments to municipalities for emergencies, critical infrastructure investments in adaptation and vulnerability reduction (DIPRES 2015). We expect that more transfers mean more investments in DRR. The source was records of transfers for 2009–2014 available at ministries' websites.

The variable "Municipal Council Autonomy Index" quantifies with binary criteria (0,1) regulatory information about the degree of municipal council autonomy using an index (0 to 1) that considers the autonomy of the councilors to form study commissions without the mayor's intervention, open access to information from municipal departments without arbitration by the mayor, possibility of meetings and public hearings with external actors, and procedural rules on the participation and free expression of the councilors during council meetings. With the same criteria, the variable "Municipal Organisation Index" quantifies information on the internal regulations and municipal organigrams considering the existence of formal offices for emergencies and environmental protection, municipal offices and/or personal for environmental management in SECPLA and existence of technical or coordination committees. The political competition variable "Mayor Affinity in Municipality Council Index" refers to the votes obtained by councilors close to the mayor's party with data from the Electoral Service (available at www.servel.cl). We expect that weaker political competition means fewer investments in DRR. The accountability variable transparency consists of municipal rankings of the national Council for Transparency (2019). Additionally, we expect effects of two staff variables, the number of contracted professionals for environmental management and for municipal emergency jobs. Representing subjective factors potentially influencing councils' decisions, we include the nominal variable ideology of mayors.

Two linking SC variables contain percentages of participation in territorial social organizations with information from 2009, 2011 and 2013 CASEN surveys (Ministry of Social Development, 2011, 2013, 2015), and rate of registered organizations for every 1,000 inhabitants with databases from the Civil and Identification Registry (available at www.registrocivil.cl).

As municipal context variables, we take in annual precipitation, Mercalli magnitude point of the 2010 earthquake, number of years since the earthquake that had a sizable negative impact, number and cost estimations of extreme events between 1971 and 2011, population density, urban population and location of the municipality (coast, valley or mountain).

The database has multiple budgetary and investment decisions of 329 Chilean municipalities between 2009 and 2014. We estimate equations for the three dependent variables after adding a small constant and taking the natural logarithm. With these specifications, the coefficients represent percentage changes of the dependent variable when there are changes in the respective explanatory, all else equal. The advantage of this approach is that coefficients are unit free. We use linear fixed effects (LFE) and random effects (LRE) models for estimating equations.

Results

Table 3 contains the results of the linear panel data regressions. The columns contain the estimations of LFE and LRE models for each dimension of DRR (emergency funds, critical infrastructures for adaptation and vulnerability reduction). All specifications include year fixed effects as well. Estimated coefficients are above their municipal-level, clustered standard errors in parentheses, which take into account correlation induced by unobserved heterogeneity at the local government level.

Emergency funds per inhabitant (columns 1 and 2) are not significantly affected by MLG variables, ie, transfers coming from upper-level government. A rise of 1% in the number of personnel devoted to municipal environmental chores increases the expenditure in emergency funds per inhabitant by 0.2%–0.3%. An increase of one unit of our measure of transparency significantly increases the amount of emergency funds per inhabitant by 0.15% in the LFE model. Regarding linking SC, an increase of one community organization per 1,000 inhabitants positively increases emergency funds by 0.18%–0.20% in both LFE and LRE models.

Context variables also help explain emergency fund variations across municipalities and over time. The Mercalli magnitude of the 2010 earthquakes highly positive and significant, suggesting that municipalities severely affected by the earthquake increased their expenditures by nearly 9.35% per Mercalli magnitude point and leading to a tremendous impact on budget decisions. The LRE model portrays a still remarkable, but somewhat milder effect. Reduction of rain level leads to a decrease in emergency funds in this model. The interaction between the same Mercalli magnitude and the variable taking the number of years since the earthquake has a sizable negative impact, implying sharp increases in emergency fund expenditures and subsequent reductions. Finally, an increase of 1% in poverty in the municipality leads to a 0.34% increase of emergency funds on average.

Table 3. Estimation results of fixed effects (FE) and random effects (RE)

Part 1

VARIABLES	(1) FE log(emerg funds m$/hab)	(2) RE log(emerg funds m$/hab)	(3) FE log(inv adapt/hab)	(4) RE log(inv adapt/hab)	(5) FE log(inv vulner/hab)	(6) RE log(inv vulner/hab)
log(SUBDERE neighb transf/hab)	0.00224 (0.00874)	0.00446 (0.00621)	0.0485* (0.0283)	0.0819*** (0.0278)	0.0534 (0.0346)	0.0810*** (0.0301)
log(SUBDERE manag transf/hab)	-0.00689 (0.0104)	0.00204 (0.00623)	-0.00433 (0.0283)	0.0105 (0.0272)	-0.0259 (0.0302)	-0.000130 (0.0286)
log(MININT local transfer/hab)	0.0305 (0.0258)	0.0355 (0.0226)	-0.0120 (0.0791)	0.0371 (0.0701)	-0.0130 (0.0904)	0.00619 (0.0828)
log(MINAGRI local transf/hab)	-0.0150 (0.0223)	-0.00105 (0.0160)	0.00227 (0.0918)	0.0577 (0.0798)	0.0508 (0.106)	0.0989 (0.0860)
log(MMA local transfer/hab)	-0.238 (0.372)	-0.0740 (0.341)	0.466 (0.599)	0.657 (0.596)	1.086* (0.632)	1.037* (0.611)
log(curr reg transf/hab)	0.00914 (0.0497)	-0.0408 (0.0270)	0.414** (0.176)	0.442*** (0.143)	0.164 (0.191)	0.257* (0.152)

Part 2

VARIABLES	(1) FE log(emerg funds m$/hab)	(2) RE log(emerg funds m$/hab)	(3) FE log(inv adapt/hab)	(4) RE log(inv adapt/hab)	(5) FE log(inv vulner/hab)	(6) RE log(inv vulner/hab)
mun council autonomy index		-0.0249 (0.0611)		-0.320 (0.249)		0.0144 (0.283)
mun org index		0.943*** (0.133)		0.604 (0.415)		0.215 (0.495)
mayor affinity in mun council	0.0728 (0.0992)	0.0318 (0.0733)	-1.001** (0.494)	-0.786** (0.337)	-1.012* (0.588)	-0.970** (0.384)
envir contract rate	0.00238* (0.00125)	0.00343** (0.00146)	-0.0143* (0.00788)	-0.0142** (0.00628)	0.00396 (0.0125)	0.00431 (0.0112)
emerg contract rate	0.00115 (0.00160)	0.00124 (0.00127)	0.0219*** (0.00449)	0.0130** (0.00601)	0.0209** (0.00854)	0.0136 (0.00861)
transpar goal rat	0.00155** (0.000611)	0.000497 (0.000381)	-0.000278 (0.00290)	-0.00210 (0.00222)	-0.00170 (0.00348)	-0.00270 (0.00262)
Centre-right mayor	-0.0596 (0.0550)	0.0193 (0.0327)	0.102 (0.282)	0.142 (0.172)	0.0937 (0.334)	0.215 (0.201)
Centre-left mayor	-0.0209 (0.0533)	0.0173 (0.0391)	0.215 (0.251)	0.163 (0.180)	0.287 (0.306)	0.308 (0.207)

Part 3						
	(1)	(2)	(3)	(4)	(5)	(6)
	FE	RE	FE	RE	FE	RE
VARIABLES	log(emerg funds m$/hab)	log(emerg funds m$/hab)	log(inv adapt/hab)	log(inv adapt/hab)	log(inv vulner/hab)	log(inv vulner/hab)
social particip rate	0.00100	0.00421**	-0.000623	0.00142	-0.00385	0.00645
	(0.00208)	(0.00184)	(0.0109)	(0.00663)	(0.0137)	(0.00764)
community org rate	0.00186***	0.00200***	2.05e-05	0.000256	-0.00445	-0.00344
	(0.000527)	(0.000589)	(0.00270)	(0.00234)	(0.00299)	(0.00237)
log(rain mm)	0.0317	-0.0398***	-0.0170	-0.0180	0.0236	0.0554
	(0.0330)	(0.0114)	(0.134)	(0.0437)	(0.165)	(0.0424)
mercalli X post 2010 earthqk	0.0935***	0.0618***	0.0124	-0.0666	-0.0436	-0.0865
	(0.0206)	(0.0156)	(0.0578)	(0.0545)	(0.0707)	(0.0652)
mercalli X years after 2010 earthqk	-0.0235***	-0.0206***	-0.00419	-0.00772	-0.0205	-0.0243
	(0.00442)	(0.00453)	(0.0170)	(0.0180)	(0.0209)	(0.0217)
log(num extr event)		0.00739		0.0558		0.188*
		(0.0185)		(0.0949)		(0.103)
log(cost extr event)	0.000602	-0.00135**	-0.00709	-0.00488	-0.00541	-0.00524
	(0.00113)	(0.000663)	(0.00535)	(0.00306)	(0.00584)	(0.00325)
population density		0.000489		-0.0716***		-0.0979***
		(0.00356)		(0.0267)		(0.0347)
poverty rate	0.00346**	0.000663	0.00381	0.00462	-0.000911	0.00434
	(0.00164)	(0.00111)	(0.00761)	(0.00592)	(0.00827)	(0.00629)
urban rate	0.000602	-0.00135**	-0.00709	-0.00488	-0.00541	-0.00524
	(0.00113)	(0.000663)	(0.00535)	(0.00306)	(0.00584)	(0.00325)
coast	-0.0423		0.366**		0.320*	-0.0423
	(0.0298)		(0.159)		(0.177)	(0.0298)
valley	-0.0617**		-0.428***		-0.440**	-0.0617**
	(0.0255)		(0.162)		(0.184)	(0.0255)
Part 4						
Wald Test						
Observations	1,757	1,737	1,757	1,737	1,752	1,732
Number of munic	329	324	329	324	328	323
R-squared	0.179		0.076		0.045	
R-sq overall	0.0227	0.435	0.156	0.257	0.143	0.234
R-sq between	0.0411	0.665	0.196	0.382	0.239	0.383
R-sq within	0.179	0.180	0.0761	0.0657	0.0452	0.0368
error SD	0.485	0.329	1.784	1.539	1.934	1.688
Test all	2.78e-08	1.97e-08	0.000720	0	0.0367	1.20e-09
Test ML Gov	0.614	0.317	0.180	0.000349	0.354	0.0111
Test Inst	0.0266	0.0771	8.03e-06	0.00587	0.0368	0.0299
Test Soc Cap	0.00218	0.000318	0.998	0.969	0.278	0.314

*** p < 0.01, ** p < 0.05, * p < 0.1

Notes: SUBDERE, Undersecretary of Regional and Administrative Development; hab, inhabitant; MININT, Ministry of the Interior; MINAGRI, Ministry of Agriculture; MMA, Ministry of Environment. Municipal-level clustered standard errors are in parentheses. Added controls are explained in the text. Hypothesis tests are Wald.

At the end of Table 3, we use a Wald test to discover if any factors can significantly explain time and cross-sectional variations of the dependent variable, a clearly rejected hypothesis. Next, we test if multilevel governance variables do not explain emergency fund determinations, which is not rejected (*p*-value 0.614). The hypotheses that political-institutional factors and SC variables are not explicative are clearly rejected at 5% significance.

The level of municipal investment in critical infrastructure for adaptation per inhabitant (columns 3–4 of Table 3) is positively affected by transfers from the Undersecretary of SUBDERE to invest in neighborhoods. An increase of 1% in these transfers generates 0.048%–0.082% increase in adaptive investment. Transfers coming from the regional government have a sizable impact: an increase of 1% leads to a 0.4% increase in adaptive investment at the municipal level. Municipal institutional aspects also affect these expenses. A greater political affinity between the mayor and councilors tends to decrease the level of adaptive investment by a large margin. An increase in the share of environmental specialists at the municipal level increases the level of adaptive investment per inhabitant. Emergency officials know the community, collect data on the ground, and therefore provide valuable information for decisions on adaptation. On the contrary, increasing the number of environmental specialists generates the opposite effect on average. SC measures and ideologies do not affect this kind of investment.

From the context variables, higher population density tends to decrease the expense per inhabitant, suggesting some scale or agglomeration economies in providing adaptation in larger urban centers. Finally, geography matters: municipalities with shores on the Pacific Ocean tend to invest more than the omitted mountain group (Andean municipalities) in this category, while those lying in the valleys follow the opposite behavior on average.

Wald tests indicate that we reject irrelevance of some of the portrayed factors, but we cannot do so for linking SC variables in this case. Institutional factors jointly play a role for determining adaption investments. The LFE model cannot reject the joint irrelevance of MLG factors at conventional significance levels, but we clearly reject this in the LRE model.

Investments in critical infrastructures to reduce vulnerability in columns 5 and 6 (Table 3) are affected by SUBDERE investments in neighborhoods (only LRE), and with less confidence, by regional government transfers per inhabitant. Affinity between mayor and councilors negatively impacts the level of these investments on average. A larger share of emergency specialists in a municipality significantly increases the level of investment in vulnerability reduction.

As in the case of adaptation investment, a negative impact of population density suggests scale or agglomeration economies providing vulnerability reduction. Also, coastal municipalities invest in vulnerability reduction more on average than their mountain counterparts, the reference group. In turn, municipalities located in the central valley invest less than those in the reference group.

The evidence shows that MLG and institutional factor significantly account for time and cross-sectional variation of vulnerability attenuation investment. In contrast, the linking SC variables do not play an important role in explaining this kind of investment.

All in all, the evidence in the tables supports a multidimensional estimation for the study of local government responses when facing environmental risks. Each dependent variable, a particular measure of the underlying DRR investment, exhibits a different mix of critical determinants, leading to a nuanced vision of the institutional determinants of local government decisions in DRR.

Conclusion

The quantitative exploration supports evidences of the qualitative analysis about the effects institutional, linking social capital (SC), and multilevel governance (MLG) variables. In the first two models (emergency funds), internal organization and transparency, the staff for emergencies, social participation and community social organizations have positive effects on budget decisions with statistically significant coefficients. In the critical infrastructure investments for adaptation and vulnerability reduction models, SUBDERE and regional government transfers have positive effects, having more emergency specialists increases the likelihood of investments, and mayor affinity in municipal councils has negative effects. Considering the independent variables as a whole, the conclusion is that the linking SC, MLG interactions, and some of the identified municipal institutional factors have effects on local government decisions in DRR, but differentiated.

Social participation and community organizations represent a form of linking SC with the potential to positively influence municipal decisions, since they are in a position to introduce information and incentives in the council's agenda so that local politicians' priorities these topics in their decisions (e.g., case study). Under risk situations and disasters, individuals and organizations may mobilize their social resources and exert direct pressure on municipalities, creating incentives for better prevention. Additionally, social participation correlates with positive effects of municipal commitments on emergency funds. This leads to the conclusion that the combination of "well-functioning" municipalities and linking SC manifest in the area of prevention.

On the other hand, similar to the situation in Cauquenes and Lebu, linking SC does not have similar effects on adaptation and vulnerability reduction investment in a larger number of Chilean municipalities. This fact suggests that social participation and organizations are not connecting adequately with municipal decision making or, alternatively, existing interactions do not lead to the theoretically expected effects.

To improve DRR, one cannot look only at natural risks or at local governments in isolation from other organizations and society; one has to understand how the system works, and the interactions between multiple cross-scale actors, barriers and enablers. The municipal government system is institutional, social and interlocal, interconnected. This is why we see relationships between the municipality and these different levels: municipalities, regional government, ministries, linking social capital. For this reason, we see failures and successes related to DRR.

Research has to look carefully at the relationships between various levels of government and society to understand outcomes. If we want to strengthen DRR at the local level, we must recognize that we have to move beyond specific factors, drivers or individual organizations to an approach of governance in a multisystem perspective to achieve a better understanding about links, connections and causal relationships. We have to recognize the link with organizations and pay more attention to how well the overall system performs.

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