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Theory and Evidence from Latin America and the Caribbean

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Estimating the Economic Impact of Governance in Disaster Risk Management: Theory and Evidence from Latin America and the Caribbean

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Strengthened governance is crucial to reduce economic risks associated with disasters, but little is known about its impact. We combine a new dataset on disaster risk management governance for 26 countries from the Latin America and Caribbean region with annual information on economic losses resulting from disasters between 1980 and 2016. To account for endogenous disaster risk management (DRM) governance processes, we exploit the fact that changes in DRM regulatory frameworks affect a country's capacity for disaster risk identification and reduction to provide instrumental variable estimates of their impact. We find that disasters cause substantial economic losses and that a more robust governance for disaster risk resilience to economic losses reduces the expected economic toll caused by nature's shocks. Our estimates suggest that the improvement of DRM governance in Latin America and the Caribbean mitigate the economic toll of disasters, especially in a context where climate change leads to the occurrence of more frequent and severe natural hazards across the region.

Keywords: disaster risk resilience, governance, economic losses, Latin America and the Caribbean

JEL Classification: O54, Q54, Q58

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1. Introduction

The catastrophic earthquake of September 19th, 1985 remains in the collective memory of Mexico not only for the massive destruction it caused in entire blocks of central Mexico City, but also because it is the deadliest disaster in the history of the Mexican capital. For the second time on a September 19th, a devastating earthquake struck Mexico City in 2017. It was the costliest disaster of the year in the developing world, causing overall losses of approximately US\$ 6 billion. With 369 fatalities, it was also the second deadliest disaster worldwide for that year, behind only the Freetown landslides in Sierra Leone, which killed at least 500 people (Munich Re 2018).

The Mexico City earthquake is a reminder that not only disasters in the Latin America and Caribbean (LAC) region are on the rise, both in terms of recurrence and intensity, but also that their impact is increasing with respect to economic costs. While in 1980 there were 61 relevant disasters on record, in 1990 there were at least 75 disasters. In 2000, 98 events took place, and in 2010 the number escalated to 162 disasters. In 2016, LAC was hit by 323 disaster events, twice as many as in 2010. The same trend is observed for those disasters considered highly destructive¹. While in 1980 there were only 5 catastrophes on record, the figure rose to 12 in 2016².

Between 1980 and 2016, the LAC region was struck by 4,125 disasters, where at least 292,361 people lost their lives. These losses accounted for 282 billion dollars (inflation-adjusted). On average, every hour, the region loses 1.2 million dollars because of a disaster. To put the figure in perspective, the annual cost of

¹ We use Munich Re's (2017) classification methodology to categorize disaster intensity, whereby the degree of severity of an event depends on the particular income group of the affected country. An event is considered highly destructive if it caused economic losses greater than US\$100 million in low-income countries, US\$300 million in lower-middle countries, US\$1 billion in upper-middle countries, or US\$3 billion in high-income countries. Low-income economies are defined as those with a per capita income, calculated using the World Bank Atlas method, of \$995 or less in 2017; lower middle-income economies are those with a per capita income between \$996 and \$3,895; upper middle-income economies are those with a per capita income between \$3,896 and \$12,055; high-income economies are those with a per capita income of \$12,056 or more.

² Since 1980, seven events have exceeded 5 billion dollars in economic losses: the Vargas landslide in Venezuela (5,177 million), the Mexico City earthquake of September 2017 (6,000 million), Hurricane Ike in Cuba (7,073 million), the 2010 Haiti earthquake (7,447 million), Hurricane Mitch (Honduras, 7,772 million), and the earthquake in Mexico City in September 1985 (8,117 million). The most expensive event in the region's recent history, however, is the devastating 2010 earthquake in Chile, causing over 27,666 million dollars in damages.

disasters in the region is equivalent to six times the GDP of Belize, is 35 times greater than the budget Mexico allocates to public policies for the development of indigenous peoples and communities, and it would be enough to cover (and increase by 39%) the public spending of the prison systems of all the countries of the region (Guerrero Compeán 2018).

Disasters epitomize decades of development policies that, in the context of disorganized urbanization, unregulated land-use planning and accelerated industrialization, have failed to reduce socioeconomic vulnerability, particularly among the poor (Hallegatte et al. 2016). Hazards such as floods, storms and earthquakes are naturally occurring; disasters are not. They are the product of unfavorable social, economic and institutional processes that hinder resilience to shocks and make a society more vulnerable as a result (Wisner et al. 2005). For instance, a stark illustration of the combined impact of the institutional and socioeconomic environments is the magnitude-7.0 2010 Haiti earthquake, which killed at least 160,000 people, an unprecedented death toll for an event of this magnitude, whereas one month later, Chile was affected by a magnitude-8.8 quake that caused 520 fatalities (Kolbe et al. 2010, Munich Re 2018). The fact that an earthquake that was approximately 500 times more powerful than another only led to 99.7% fewer casualties suggests that settlements in risky areas, infrastructure underinvestment resulting from low levels of income, lack of enforcement of strict building codes in an earthquake-prone region, and widespread corruption subverting construction oversight may be better predictors for disaster impact than the natural environment per se (Ambraseys and Bilham 2011, Escaleras, Anbarci, and Register 2007, Lall and Deichmann 2012, van Galder 2010).

Alexander (2000: 13) proposes that vulnerability “refers to the potential for casualty, destruction, damage, disruption, or other form of loss in a particular element”, whereas risk “combines this with the probable level of loss to be expected from a predictable magnitude of hazard”. Such notions suggest that Haiti (and the LAC region as a whole) is at a high risk of disasters because its society is highly vulnerable to natural hazards. It is implied then that risk is defined as a function of the occurrence of a physical shock and the vulnerability of the exposed unit caused by socioeconomic and institutional pressures (Blaikie et al. 1994). Because there is a socioeconomic and institutional causation to disasters, Burton, Kates and White (1993) argue that improved institutional structures reduce the vulnerability to hazard impacts. Ahrens and Rudolph

(2006) demonstrate that only if a country's governance structure enables the implementation and enforcement of disaster risk management (DRM) policies can susceptibility to disasters be reduced.

In effect, developing and consolidating the governance of disaster risk is a *sine qua non* condition for sustainable development (Wisner et al. 2003). Although it must be recognized that natural hazards are a latent threat to social welfare, the action of the State through the implementation of adequate public policies plays a key role in counteracting the potential effects caused by these threats. Guerrero Compeán et al. (2017) highlight several aspects that should be considered within the framework of State action for an effective DRM, including the establishment of the legal, institutional and budgetary basis for: (i) the coordination of the disaster risk management policy and the definition of responsibilities at sectoral and territorial levels; (ii) the identification and reduction of risks; (iii) the disaster preparedness for an effective response; (iv) the planning to ensure a swift and resilient recovery, and (v) the financial protection. These aspects are directly related to reducing the vulnerability of society and strengthening the resilience of communities, particularly the poor (IDB 2015). Particularly, as we will later empirically demonstrate, risk identification and reduction are also critical mechanisms through which disaster resilience to economic losses (REL) may be attained.

Although the theoretical proposition that the enhancement of DRM governance and REL conditions as a mechanism supporting risk reduction is well documented in the literature (see Wisner et al. 2005 for a review), empirical evidence on the effect of improvements in the structure of governance in DRM on risk reduction is surprisingly scant. In previous research, we showed that disaster risk governance indicators are negatively correlated with national-disaster death counts (Guerrero Compeán et al. 2017), but this line of research should be further explored. For instance, there is, to our knowledge, no empirical support for the argument that strengthened REL can reduce economic losses resulting from disasters. If empirical evidence were available, policy decisions aimed at fostering solid disaster resilience to economic loss in the face of natural catastrophes could be *prima facie* economically and politically justified, opening the possibility of approaching REL as a development strategy. This work attempts to provide robust evidence to this end.

We acknowledge that REL, and DRM governance structures as a whole, develop in tandem with other potential determinants of economic losses. Several factors, such as the effects of past disasters, may affect REL processes.³ Hence a simple comparison of outcomes in countries with solid versus incipient REL governance structures is unlikely to provide an unbiased causal estimate of the impact of governance on economic losses. As countries where we see higher economic losses are also more likely to show more advanced REL governance structures, a potential double causality (or endogeneity) problem arises. To address this, we will exploit the structure of a six-component DRM governance index (iGOPP) for LAC countries in which components of the regulatory framework, disaster preparedness, recovery planning and financial protection are clearly distinguished from those related to countries' capacity for disaster risk identification and reduction. In other words, we will instrumentalize the potentially endogenous impact variable (capacity for disaster resilience to economic loss) using index components directly related to changes in the regulatory, financial and enabling environment for advancing stronger DRM policies.

The remainder of the paper proceeds as follows: Section 2 offers insights about the economic impacts of REL and DRM governance structures, while Section 3 provides a conceptual framework for assessing the economic implications of changes in REL and other variables. Sections 4 and 5 describe the data and our empirical strategy, respectively. Section 6 discusses the empirical results, and Section 7 includes alternative specifications and robustness checks for the estimated models. Section 8 presents our main conclusions and some policy implications.

2. Insights about the economic impact of DRM: a review of the literature

Research in the area of DRM governance is nascent but has significantly expanded over the past two decades (see Figure 1). The primary focus of this new research field remains largely conceptual, driven by theoretical discussions on what constitutes good DRM governance and its effects on relevant DRM outcomes, with empirical assessments and applied research on the effectiveness of governance remaining

³ For instance, the Mexican General Civil Protection Act of 1986 was passed after the 1985 Mexico City earthquake, and the National Disaster Prevention and Attention System of Colombia (1988), was established after the Armero tragedy of 1985.

a systemic knowledge gap (Gall, Cutter and Nguyen 2014). Most applied publications focus, however, on the impact **of** disasters on a range of both micro and macroeconomic outcomes at different levels of development (Strömberg (2007) and Cavallo and Noy (2009) review this field of research), with a surprisingly limited number of studies analyzing the factors that have an impact **on** the magnitude of disasters. One of the most well-known publications of this latter category is the analysis of Kahn (2005) on the role of income, geography and institutions on annual deaths from disasters. We built on that research and evaluated the impact of DRM governance on disaster-related fatalities for a subset of LAC countries (Guerrero Compeán et al. 2017).

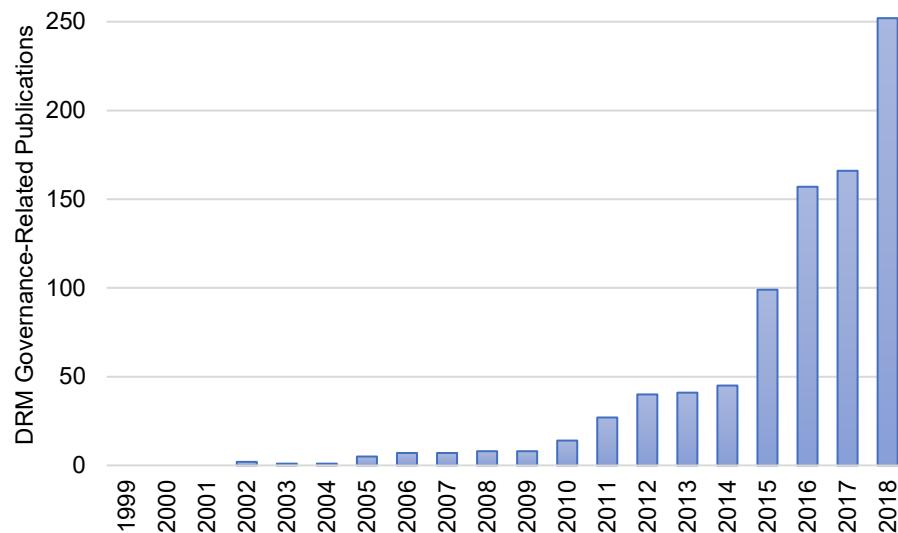


Figure 1. Disaster risk management governance-related publications, 1999-2018

Source: The authors.

The role of socioeconomic and institutional factors on the effects of disasters

The extent to which a country is affected by disasters is associated with a range of socioeconomic and institutional factors. Among them, Kellenberg and Mobarak (2011) identify institutional quality, including measures of democracy, educational attainment of the population, level of corruption, macroeconomic

conditions, income inequality, and ethnic fragmentation, as relevant dimensions for disaster magnitude. Guha-Sapir et al. (2012) also suggest that countries with higher social capital have relatively fewer disaster-related fatalities.

In a panel study, Noy (2009) shows that smaller or less developed countries are less able to insure against disasters, because their economies are not as diversified in their productive capacity and financial markets, thus increasing their adverse effects on the gross domestic product. Larger economies have also been found to be more resilient to disasters by Hallegatte and Ghil (2008). Using information on disaster mortality in 73 countries from 1980 to 2002, Kahn (2005) finds that upper-income countries suffer fewer disaster-related fatalities as richer governments are able to provide better infrastructure as well as implicit disaster insurance through regulation, an argument echoed by Tol and Leek (1999). With microdata for 416 and 850 households in Ethiopia and Honduras, respectively, Carter et al. (2007) conclude that the lower the income, the more severe the disaster impact, since lower-income households are less able to access capital markets and recover more quickly. Albala-Bertrand (1993) collects disaster data from 1960 to 1979 in low- and middle-income countries and shows that economic development leads to lower material losses caused by disasters. Overall, more economic resources have been associated with improved capacity for disaster prediction, protection and mitigation, thus reducing the economic impact of disasters (Escaleras and Register 2008, Horwich 2000, Shaari et al. 2016).

Eisensee and Strömberg (2007) attribute the lower human and economic costs of disasters in developed countries to access to better housing, early warning systems, medical care and better evacuation plans. Kellenberg and Mobarak (2008), however, hypothesize that the relationship between economic development and vulnerability to disasters is nonlinear, with risk increasing with higher incomes, as people with higher incomes have a higher propensity to residing in highly exposed locations, such as the coast.

Toya and Skidmore (2007) examine additional economic factors such as a strong financial sector and the degree of trade openness, finding that both solid financial markets and openness decrease disaster losses. These results are consistent with the findings of Yang (2008). In later research, these authors also conclude that a higher cellphone penetration leads to reduced disaster fatalities, with the effect being stronger for events where there is typically no warning (Toya and Skidmore 2018). Wang, et al. (2016) explore the use

of social media in emergency response in China during the 2012 Beijing rainstorm, demonstrating that real-time dissemination of emergency information from social media facilitates emergency response processes.

In terms of the role of institutions on disaster impact, results from analysis of data of almost 2,800 large-scale disasters between 1984 and 2004 carried out by Raschky (2008) show that countries with better institutions experience fewer fatalities and lower economic losses from disasters. Kahn (2005) also concludes that better institutions reduce disaster impact. Anbarci, Escaleras and Register (2005) study the relationship between income inequality and earthquake fatalities, reporting that inequality increases disaster-related mortality because an uneven distribution of resources is suggestive of a nation's inability to adopt disaster risk preventive measures and policies for vulnerable populations. Escaleras et al. (2007) develop an economic model of corruption showing that public sector corruption has a positive effect on earthquake-related fatalities. Besley and Burgess (2002) show that newspaper circulation is negatively associated with flood impacts in India, as the state has a more active role in disaster prevention and mitigation when the government is more likely to be held accountable by mass media.

DRM governance and its role on economic loss reduction

The Third UN World Conference on Disaster Risk Reduction in March 2015 adopted the Sendai Framework for Disaster Risk Reduction 2015-2030, a global plan to mitigate disaster risk. The framework underscores the role of DRM governance in reducing disaster economic losses. Strengthening disaster risk governance to manage disaster risk efficiently is one of the four priority areas of the Sendai Framework to achieve the global target of “reducing direct disaster economic loss in relation to global gross domestic product by 2030”, as improved disaster risk governance “is vital to the management of disaster risk reduction in all sectors and ensuring the coherence of national and local frameworks of laws, regulations and public policies that, by defining roles and responsibilities, guide, encourage and incentivize the public and private sectors to take action and address disaster risk” (UNISDR 2015, p. 36). In particular, emphasis should be placed in disaster risk identification and reduction efforts by including disaster risk identification and reduction in legal and institutional frameworks, within relevant sectors and at all government levels, if disaster resilience to economic loss is a factor of consideration (UNDP 2014). This is so because disaster risk governance

requires the integration of disaster risk considerations into sustainable development policies and development planning and programs, together with the development of stronger institutions, mechanisms and community capacities that can systematically build resilience to natural hazards and disasters (UNDP/BCPR et al. 2005).

Ahrens and Rudolph (2006) argue that only if a country's governance structure enables the implementation and enforcement of public policies fostering accountability, participation and predictability can susceptibility to disasters be reduced. The Global Assessment Report on Disaster Risk Reduction (GAR11) makes the direct correlation between disaster-related economic losses and the limited disaster risk management governance. Even though many countries have carried out policy reform processes to strengthen DRM, existing risk governance arrangements remain inappropriate, and deeper reform is therefore fundamental to reducing disaster risk (UNISDR 2011). Stromberg (2007) and UNISDR (2011) conclude that poor governance influences higher disaster fatalities and economic losses. In effect, DRM governance can create political incentives that lead to disaster risk reduction. For instance, countries with effective institutional mechanisms conducive to accountability tend to invest more in DRM and exhibit lower disaster-related mortality rates (Anbarci, Escaleras and Register 2005, Scott and Tarazona 2011). In a seminal essay, Sen (1982) argues that disasters are not caused by exposure to hazards per se, but rather weak governance. Clague (1997) consequently, concludes that susceptibility to disasters is a consequence of institutional failure.

3. A conceptual framework for the economic implications of disaster resilience to economic loss (REL)

The objective of this paper is to portray the relationship between disaster REL and economic losses resulting from disasters. We present a conceptual framework that relies on the models of risk and self-insurance by Schumacher and Strobl (2008) and Lewis and Nickerson (1989).

Assume that the occurrence of a disaster is an event with probability $p \in (0,1)$ and, if a disaster takes place, wealth $w > 0$ decreases by a percentage equal to $1 - \varphi(g, y) \in (0,1)$, where y is the intensity of a disaster

and g is the level of REL, which is attained with a cost of $c > 0$. Economic losses are defined by $L(w, g, y)$ and, therefore, $u(I) = w - cg - L(w, g, y)$ where $u(\cdot)$ is a well behaved utility function and I is total net wealth for a given country.

Schumacher and Strobl (2008) use this model to study the relationship between expected economic losses and a country's level of development (proxied by w). In their model this relationship is influenced by the frequency and intensity of disasters (y), and by the level of expenditure on risk reducing actions (g). They identify critical values for w and y above which countries will find profitable (or cost-effective) to invest in g activities that tend to reduce either the probability of disasters and/or the magnitude of economic losses. The theoretical model shows that those countries with low exposure to disasters are likely to undertake modest disaster REL processes, but as economic development takes place disaster REL becomes increasingly profitable. For high-exposure countries, consolidating disaster risk management governance is an optimal strategy, regardless of the level of wealth. These nations are expected to exhibit decreasing economic losses if the marginal benefit of REL outweighs its marginal cost. In the next section, we test empirically whether increasing levels of relevant DRM governance components (i.e., those that enhance disaster REL) do reduce the economic losses caused by disasters.

Schumacher empirical and Strobl (2008)'s implementation does not observe variable g , and the authors make assumptions for these relationships to test implications regarding expected economic losses and economic development as a result. In our case, we do have an observable index related to disaster reducing expenditures, so we will be directly interested in estimating the parameters of the economic loss function. Following Schumacher and Strobl (2008), we assume that:

$$\frac{\partial L}{\partial w} > 0, \frac{\partial L}{\partial g} < 0, \frac{\partial L}{\partial y} > 0, \frac{\partial^2 L}{\partial^2 g} > 0, \frac{\partial^2 L}{\partial g \partial y} < 0, \frac{\partial^2 L}{\partial g \partial w} < 0.$$

The first assumption implies that economic losses increase in the amount of wealth, while the second one indicates that economic losses decrease with the level of REL. The third one shows that the stronger the

disaster, the higher the expected economic losses. The fourth assumption presupposes that for very low levels of REL, marginal improvements are very effective, but as a country's REL consolidates, further improvements become less consequential in terms of economic losses. The fifth assumption implies that REL is more effective for larger disasters. Finally, it is assumed that the marginal loss for a given level of wealth decreases as REL improves.

4. Empirical strategy

The objective of this paper is to correctly identify the impact of REL on disaster-related economic losses. We are, therefore, interested in estimating the equation:

$$l_{it} = \beta_1 REL_{it} + \beta_2 D_{it} + \beta_3 \lambda_{it} + \beta_4 y_{it} + \mathbf{X}_t \boldsymbol{\Theta}_i + \epsilon_{it} \quad (1)$$

where l_{it} denotes the outcome of interest -disaster-related economic losses- in log form for country i in year t ; REL_{it} is a metric of disaster resilience to economic loss, whose operationalization is described in detail in the next section, for the country level; D_{it} is the frequency of disasters; λ_{it} is a disaster intensity metric; y_{it} is the log value of the real per capital gross domestic product (GDP); $\mathbf{X}_t$ is a vector of other time-varying controls, and ϵ_{it} is a country-year specific error term. Among the controls we include the logged values of the country's area, the log of infrastructure potentially exposed to natural hazards; the average years of education completed among people over age 15; general government final consumption expenditure measured as a share of GDP; and a normalized indicator of institutionalized democracy.

Based on the theoretical model presented in Section 3, we hypothesize that, all other things equal, increasing levels of REL reduce the economic losses caused by disasters, whereas stronger and more frequent disasters increase them. We use a quadratic form for per capita incomes -a proxy for economic development⁴- to assess its potentially nonlinear relationship with expected economic losses as in

⁴ We acknowledge that income flows are an approximation to the stock of wealth, but the correlation between these two variables is high.

Schumacher and Strobl (2008). Similarly, a growing exposure of infrastructure to natural hazards is expected to increase risk and, presumably, economic losses. Higher educational attainment is expected to lead to a better assessment of disaster risk, which in turn would result in better decision-making processes in terms of risk identification and risk reduction and thus in lower economic losses when a disaster takes place. The expected effect of size of government is open to argument. Toya and Skidmore (2007) discuss that, while larger governments have more disaster response capacity, they may also be less efficient in their response. Finally, the expected effect of institutionalized democracy is also ambiguous. On the one hand, stronger democracies are more likely to enact and enforce regulations conducive to disaster risk resilience, reflecting lower economic losses resulting from disasters. Conversely, the recent coronavirus crisis has shown that authoritarian systems have been exceptionally swift in their emergency responses. Deliberative democracies, while poorly suited to react with urgency and stringency as a result of complex bottom-up processes, are less likely to restrict vital information to guide post-disaster recovery efforts effectively (Kupferschmidt and Cohen 2020).

The occurrence of disasters has strong spatial patterns, with some countries having different levels of average exposure to different natural hazards. Differences in exposure may in turn be correlated with differences in unobservable country characteristics, such as geography or cultural traits. These characteristics are captured by country and regional fixed effects, which are included in our base specifications. Similarly, we need to account for any unobservable common environmental conditions and climatic shocks such as El Niño South Oscillation (ENSO) that change over time to avoid correlating trends in disaster incidence and economic losses. To this end, we incorporate time fixed effects in our regression. By doing so, we regress:

$$l_{it} = \beta_1 DRR_{it} + \beta_2 D_{it} + \beta_3 \lambda_{it} + \beta_4 y_{it} + \mathbf{X}_t \boldsymbol{\theta}_t + \nu_i + \mu_t + \epsilon_{it} \quad (2)$$

If the regression above is estimated using ordinary least squares (OLS), then the identification assumption needs to be that the annual variation in disaster risk reduction levels across countries is uncorrelated with

other country-specific shocks. However, we may expect this assumption to be violated. As illustrated in the conceptual framework, we may expect a relatively more advanced REL in countries that are more prone to the occurrence of natural hazards or exhibit a higher disaster risk. Therefore, in addition to OLS estimates, we also report instrumental variables estimates.

Our equation is estimated for an aggregated sample of 26 LAC countries. Our sample spans 1980 to 2016. It is plausible that any given country can experience more than one disaster in a given year, while in other years no disasters take place. Table 1 provides descriptive statistics.

Table 1. Summary statistics

Variable	Observations	Mean	Standard deviation
Total population	962	18.9	36.5
Exposed propulation (millions)	962	9.4	14.4
Exposed population to geophysical disasters (millions)	962	9.0	14.5
Exposed population to meteorological disasters (millions)	962	1.5	6.4
Exposed population to hydrological disasters (millions)	962	1.2	2.5
Exposed population to climatological disasters (millions)	962	0.1	0.3
Exposed build-up area (sq. km)	962	796.4	1,315.8
Exposed build-up area to geophysical disasters (sq. km)	962	756.3	1,327.7
Exposed build-up area to meteorological disasters (sq. km)	962	154.9	681.2
Exposed build-up area to hydrological disasters (sq. km)	962	121.0	250.6
Exposed build-up area to climatological disasters (sq. km)	962	526.1	1,409.1
GDP per capita*	962	7,037.3	6,537.1
Annual total economic losses*	962	450.0	2,011.7
Annual economic losses, geophysical disasters*	962	135.8	1,602.3
Annual economic losses, meteorological disasters*	962	126.8	810.1
Annual economic losses, hydrological disasters*	962	134.1	827.6
Annual total losses, climatological disasters*	962	53.3	357.5
Annual total count of disasters	962	3.6	4.4
Annual count of geophysical of disasters	962	0.6	1.2
Annual count of meteorological disasters	962	1.0	1.8
Annual count of hydrological disasters	962	1.6	2.2
Annual count of climatological disasters	962	0.4	0.8
Duration (days) of catastrophic disasters	962	8.8	95.6
Duration (days) of catastrophic geophysical disasters	962	0.1	2.1
Duration (days) of catastrophic meteorological disasters	962	0.3	2.5
Duration (days) of catastrophic hydrological disasters	962	1.8	15.5
Duration (days) of catastrophic climatological disasters	962	6.6	94.3
Disaster Risk Reduction Governance Index (unweighted)	962	10.5	13.5
Disaster Risk Reduction Governance Index (weighted)	962	11.6	15
Government consumption expenditure as % of GDP	962	13.5	5.2
Liquid liabilities (m3) as % of GDP	962	929.1	793.4
Years of total schooling, age 15+	962	7.4	1.8
Openess index	962	72.4	38.6
Normalized polity score	962	0.8	0.2

* Annual economic losses and GDP per capita are measured in constant 2016 US\$

5. Data

We used data from several sources. The dependent variable in our empirical model is the annual overall disaster economic loss, expressed in U.S. dollars of 2016. We obtained data for the 26 IDB member countries⁵ encompassing a time span of 37 years (1980-2016) from NatCatSERVICE, a global database of natural catastrophe data, whose access was provided by MunichRe (2017) upon request. Data for previous years are not deemed suitable for empirical research purposes.

Economic loss data have been normalized to make historical economic losses comparable to today's losses by considering changes in hazard-prone assets and goods at the location of the event. We use official loss estimates. We consider all geophysical, meteorological, hydrological and climatological disasters⁶. The frequency of disasters is the total number of events within these four categories in a year. Disaster intensity is measured as the aggregate length in number of days, based on the duration of the emergency declaration, of all the events themselves that took place in a given year. This information was also obtained from NatCatSERVICE.

Total exposed population data were extracted from the European Commission's Global Human Settlement Layer (Pesaresi et al. 2016). In addition, information on real per capita income (using a gross domestic product price deflator (implicit price deflator) where 2016=100) was extracted from the World Bank's DataBank (2019). To measure government size, we employ data for general government final consumption expenditures as a percentage of GDP, also from the World Bank's DataBank. To approximate educational attainment, we use the average years of education completed among people over age 15, which we obtained from the Barro-Lee Educational Attainment Dataset (Barro and Lee 2013). We use a normalized

⁵ Argentina, the Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Mexico, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and Venezuela.

⁶ We categorize disasters based on CRED and Munich Re's Disaster Category Classification and Peril Terminology for Operational Databases (Below et al. 2009). Geophysical disasters are defined as disaster events originating from solid earth (e.g., earthquakes, volcanic eruptions, and dry mass movements). Meteorological disasters are defined as disaster events caused by short-lived/small to meso scale atmospheric processes (i.e., in the spectrum from minutes to days, such as storms). Hydrological disasters are defined as disaster events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up (e.g., floods, landslides, and avalanches). Climatological disasters are defined as disaster events caused by long-lived/meso to macro scale processes (i.e., in the spectrum from intra-seasonal to multi-decadal climate variability, such as droughts, wildfires and extreme temperature conditions). We do not include biological disasters in our disaster disaggregation estimates.

polity score using data from the Polity IV Project, to assess a country's regime authority, ranging from 0 (full autocracy) to 1 (full democracy) (Marshall, Gurr and Jaggers 2016).

Finally, to measure disaster REL, we use the Disaster Risk Identification and Reduction subindices of the Index of Governance and Public Policy in Disaster Risk Management (IGOPP). The IGOPP is a composite index made up of 241 indicators encapsulated in six subindices pertaining to each DRM reform component⁷: General Framework of Governance for DRM (GF), Risk Identification and Knowledge (RI), Risk Reduction (RR), Disaster Preparedness (DP), Recovery Planning (RC), and Financial Protection (FP). The six subindices have equal weight. We will refer to the RI and RR subindices combined as the REL index. While all subindices of the IGOPP are relevant benchmarks for the existence of governance conditions that facilitate the implementation of effective disaster risk management policies, we reviewed the indicators of the six components and found that only those indicators related to RI and RR are directly related to disaster-related economic losses. The IGOPP is a national index for the full characterization of DRM governance, developed by IDB in 2012. It allows to establish whether a country has the appropriate governance conditions to implement comprehensive public policies for disaster risk management (IDB 2014). Likewise, this index is able to identify specific gaps that might exist in the legal, institutional and budgetary frameworks at the national level and thus guide the design and implementation of future policies to improve disaster risk management (Lacambra et al. 2015). The IGOPP score ranges between 0 (nonexistent governance conditions) and 100 (outstanding governance conditions) and has been computed for the 26 IDB borrowing member countries. Since the REL index only takes into account two IGOPP subindices, its maximum score is 33.3.

Figure 1 shows the average REL score for the 26 countries of Latin America and the Caribbean. Figure 2 depicts relationships between average REL scores and economic losses from disasters for the 26 LAC countries for the period 1980 to 2016.

⁷ The IGOPP methodology was revised in 2020 and, starting that year, four new indicators were added to the index. Since we only have data from 1980 to 2016, this change of methodology does not affect our analysis.



Figure 1. Average REL score for 26 countries, 1980-2016

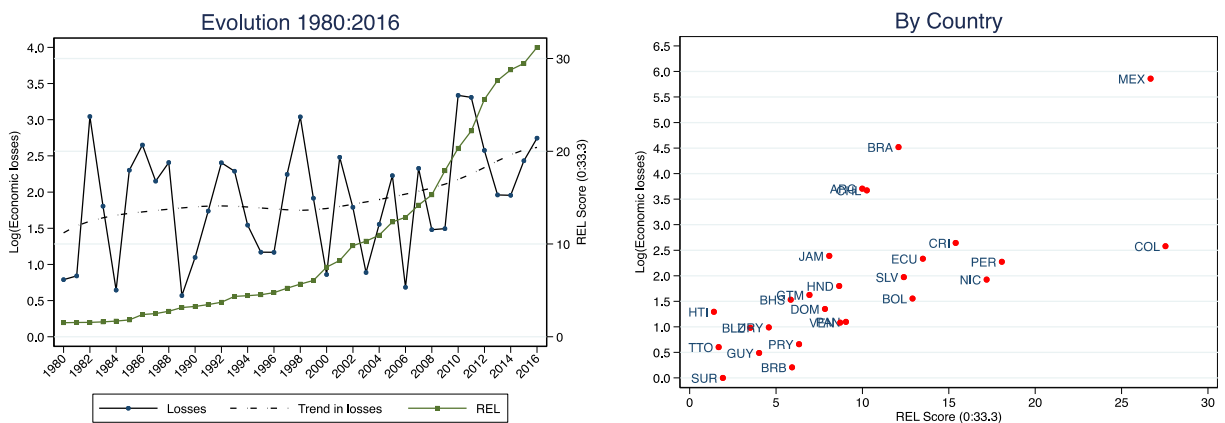


Figure 2. REL and economic losses, 1980-2016

There is a moderate upward trend in disaster economic losses in the 1980-2016 period, and a more pronounced increase in the REL score. Large nations like Mexico, Brazil and Argentina exhibit the largest losses, but medium-sized countries ones like Chile, Costa Rica, Peru and Ecuador show relatively large

losses as well. Because of their size, countries in Central America and the Caribbean tend to show minimal losses in absolute terms, but it is clear that on a per capita basis disaster-related economic losses in these regions are substantial. There is important variation in average REL scores among countries, ranging from near 0 (Suriname, Haiti and Trinidad and Tobago), to a maximum close to 30 for Colombia and Mexico. Most countries show an average REL below 20, and most of the improvement in the score has occurred after 2005.

6. Results

Prior to estimating the relationship between economic losses and REL score, we ran a probit model for the occurrence of disasters (with economic losses) for the whole sample and by type of disaster, i.e., geophysical, meteorological, hydrological or climatological. The results are shown in Table 2. For the pooled sample, the absolute latitude and landlocked situation of countries has an influence in the occurrence of disasters, with positive and negative coefficients respectively. In addition, the number of cities has a positive coefficient. There are different probabilities of disasters across regions, with the Andean countries exhibiting the highest positive coefficient for the occurrence of disasters with economic consequences (considering the Caribbean countries as the baseline region). The time trend is positive, indicating an upward evolution in the occurrence of disasters across the LAC region. These probit estimates also show different configurations for several disaster typologies. For instance, larger countries have higher probabilities of suffering hydrological and climatological disasters, whereas landlocked countries do not have a negative coefficient for climatological disasters while all other types have.

Table 2. Probit estimates of disaster occurrence associated to economic losses, 1980-2016

	Pooled	Geophysical	Meteorological	Hydrological	Climatological
Log(Area in km ²)	-0.032 (0.078)	0.083 (0.108)	0.100 (0.096)	0.148** (0.066)	0.204*** (0.068)
Log(per capita GDP, US\$ 2016)	-0.097 (0.107)	-0.011 (0.159)	-0.062 (0.092)	-0.200* (0.111)	-0.138 (0.124)
Absolute latitude	0.035** (0.016)	0.002 (0.024)	0.063*** (0.017)	0.008 (0.014)	0.019 (0.014)
Landlocked country	-1.189*** (0.347)	-1.260*** (0.315)	-0.920*** (0.278)	-0.836*** (0.188)	-0.285 (0.266)
Number of cities	0.093*** (0.014)	0.084*** (0.026)	0.028 (0.017)	0.072*** (0.014)	0.063*** (0.022)
Southern Cone	0.908* (0.515)	0.543 (0.685)	-0.373 (0.520)	0.651** (0.317)	0.289 (0.432)
Andean	1.717*** (0.438)	1.435** (0.570)	0.013 (0.497)	1.058*** (0.383)	0.300 (0.365)
Central America	0.942*** (0.188)	1.193*** (0.330)	0.302 (0.236)	0.582*** (0.208)	0.415* (0.216)
Time trend	0.039*** (0.008)	0.010** (0.005)	0.034*** (0.006)	0.040*** (0.007)	0.035*** (0.006)
Constant	-1.948 (1.284)	-4.390** (1.782)	-3.088** (1.403)	-2.904*** (1.046)	-4.682*** (1.432)
Mean probability of event	0.787	0.331	0.448	0.564	0.280
Pseudo R-squared	0.303	0.215	0.17	0.259	0.192
Observations	962	962	962	962	962

The OLS estimation for the economic loss model described in equation (2) is presented in Table 3. The REL index is used as the explanatory variable.

Table 3. OLS estimates of the effect of REL on disaster-related economic losses, 1980-2016

	(1)	(2)	(3)	(4)
Disaster resilience to economic loss (REL)	-0.015 (0.010)	-0.012 (0.014)	-0.016* (0.009)	-0.030** (0.013)
Log(per capita GDP)	-0.629 (1.572)	-1.108 (1.354)	-3.139 (3.296)	-1.279 (3.814)
Log(per capita GDP) ²	0.049 (0.094)	0.075 (0.080)	0.206 (0.210)	0.082 (0.243)
Disaster count	0.209*** (0.046)	0.215*** (0.045)	0.170*** (0.053)	0.159*** (0.052)
Duration of catastrophic disasters	0.004* (0.002)	0.004** (0.002)	0.004* (0.002)	0.004** (0.002)
Log(Area)	-0.013 (0.072)	-0.006 (0.073)	10.993*** (2.019)	13.218*** (3.033)
Log(Exposed infrastructure)	0.227*** (0.062)	0.218*** (0.061)	1.870* (0.994)	1.662* (0.893)
Log(M3/GDP)	-0.135 (0.093)	-0.167 (0.138)	-0.051 (0.107)	0.107 (0.119)
Size of government	0.019 (0.020)	0.014 (0.021)	0.024 (0.014)	0.017 (0.017)
Years of schooling	-0.002 (0.081)	0.018 (0.091)	-0.230 (0.205)	-0.256 (0.280)
Openness index	-0.001 (0.003)	0.000 (0.003)	0.000 (0.004)	0.001 (0.003)
Polity score	0.510 (0.441)	0.743 (0.484)	0.074 (0.451)	0.270 (0.521)
Constant	2.063 (6.147)	3.991 (5.403)	-125.396*** (23.276)	-158.049*** (37.866)
Country fixed effects	No	No	Yes	Yes
Time fixed effects	No	Yes	No	Yes
Adjusted R-squared	0.218	0.248	0.257	0.292
Observations	962	962	962	962

* p<0.10, ** p<0.05, *** p<0.010

We ran the model with alternative specifications for time and country fixed effects as described in the table. The REL coefficient is negative for all models, and it is statistically significant for model (3), where country fixed effects are included. Similarly, in model (4), which includes both country and time fixed effects, the REL coefficient is -0.03 and statistically significant. In other words, an additional point in the REL index is associated with a 3% reduction of the economic losses caused by disasters. More generally, a one-point

increase in the iGOPP is associated with a 3% reduction in disaster-related economic losses, provided that such a one-point increase corresponds to improvements on the IR or RR subindices. The intensity of events, measured by the frequency of disasters as well as their duration, has a positive and significant coefficient, whereas income levels measured as GDP per capita does not appear related to the magnitude of economic losses due to disasters across the LAC region. While country size shows inconclusive effects, the level of exposed infrastructure is positive and significant in all cases. The rest of control variables do not show statistical significance.

To account for endogenous DRM reform processes, we exploit the fact that changes in DRM regulatory frameworks affect a country's capacity for disaster risk identification and reduction to provide instrumental variable estimates of their impact. We use changes in the GF, DP, RC and FP components to instrument for the current existence of advances in disaster risk identification and reduction to explain economic losses. We argue that it is unlikely that the regulatory foundation for the organization and coordination of DRM, such as the availability of resources to implement DRM processes, and the establishment of adequate data and citizen participation mechanisms, as well as mechanisms for the monitoring, evaluation and follow-up of said processes, has influenced disaster-induced economic losses in any way except by fostering risk identification and supporting risk reduction capacities that minimize vulnerabilities and risk, thus preventing or mitigating the adverse social and economic impact of hazards. As discussed in Lacambra et al. (2020), the general framework of governance for DRM, along with disaster preparedness and recovery planning processes, as well as optimal financial instruments for the retention and transfer of disaster risk are strong determinants of improved disaster risk resilience to economic loss. This suggest that an instrumental variable strategy, where the non-REL components of the iGOPP are used as instruments, can be successful. Simply put, these components are more likely to capture contextual and institutional factors that shape REL measures, and only through REL decisions they have an effect on economic losses. We normalized the value of the composite sub-index to be used as instrument to have the same weight as the instrumented REL index. The IV estimates are shown in Table 4.

Table 4. IV estimates of the effect of DRR on disaster-related economic losses, 1980-2016

	(1)	(2)	(3)	(4)
Disaster Resilience to Economic Loss (REL)	-0.020*	-0.021	-0.020	-0.043***
	(0.011)	(0.015)	(0.012)	(0.012)
Log(per capita GDP)	-0.734	-1.024	-3.023	-0.657
	(1.495)	(1.469)	(3.535)	(3.480)
Log(per capita GDP) ²	0.054	0.070	0.199	0.042
	(0.090)	(0.086)	(0.216)	(0.222)
Disaster count	0.218***	0.224***	0.173***	0.164**
	(0.048)	(0.047)	(0.054)	(0.064)
Duration of catastrophic disasters	0.004**	0.004**	0.004*	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)
Log(Area)	-0.017	-0.013	10.846	13.497***
	(0.071)	(0.075)	(9.132)	(3.998)
Log(Exposed infrastructure)	0.238***	0.234***	1.878***	1.660**
	(0.063)	(0.065)	(0.622)	(0.618)
Log(M3/GDP)	-0.151	-0.162	-0.058	0.132
	(0.097)	(0.140)	(0.114)	(0.143)
Size of government	0.021	0.017	0.025	0.019
	(0.020)	(0.022)	(0.022)	(0.022)
Years of schooling	0.010	0.025	-0.201	-0.212
	(0.083)	(0.094)	(0.158)	(0.276)
Openness index	-0.001	0.000	0.000	0.001
	(0.002)	(0.003)	(0.003)	(0.004)
Polity score	0.533	0.754	0.051	0.236
	(0.424)	(0.492)	(0.417)	(0.399)
Country fixed effects	No	No	Yes	Yes
Time fixed effects	No	Yes	No	Yes
Adjusted R-squared	0.217	0.181	0.058	0.064
Observations	962	962	962	962

* p<0.10, ** p<0.05, *** p<0.010

The results of the IV regressions are similar to the OLS estimations, both in terms of sign and statistical significance of the coefficients. Even so, it is worth noting that the REL coefficients are systematically higher in absolute terms than the OLS estimates. This indicates that not addressing the endogeneity problem is likely to underestimate the impact of REL governance on disaster-related economic losses. The IV coefficient for REL in the model including time and country fixed effects, (Column (4)) is -0.043, over 40%

higher (in absolute value) than the alternative OLS regression. Based on this model, an additional point in the REL index leads to a 4.3% reduction of the economic losses caused by disasters.

We also ran the full model in Column (4) for each type of disaster. Table 5 presents the results of the IV regressions.

Table 5. IV estimates of the effect of DRR governance on disaster-related economic losses, by disaster category, 1980-2016

	(1) Pooled	(2) Geophysical	(3) Meteorological	(4) Hydrological	(5) Climatological
Disaster Resilience to Economic Loss (REL)	-0.043*** (0.016)	-0.003 (0.008)	-0.029*** (0.010)	-0.033*** (0.011)	-0.012 (0.008)
Log(per capita GDP)	-0.657 (3.646)	-3.220* (1.809)	5.086** (2.305)	-0.892 (2.577)	-1.983 (1.859)
Log(per capita GDP) ²	0.042 (0.224)	0.186* (0.111)	-0.312** (0.142)	0.074 (0.159)	0.130 (0.114)
Disaster count	0.164*** (0.029)	0.285*** (0.038)	0.279*** (0.039)	0.161*** (0.034)	0.668*** (0.056)
Duration of catastrophic disasters	0.004*** (0.001)	0.064*** (0.018)	0.219*** (0.019)	0.041*** (0.003)	0.004*** (0.000)
Log(Area)	13.497* (7.276)	-0.885 (3.692)	1.614 (4.648)	8.237 (5.012)	-2.145 (3.796)
Log(Exposed infrastructure)	1.660* (0.932)	0.210 (0.364)	0.853 (0.560)	1.236** (0.538)	0.042 (0.200)
Log(M3/GDP)	0.132 (0.137)	-0.028 (0.069)	0.050 (0.088)	0.102 (0.094)	0.067 (0.071)
Size of government	0.019 (0.022)	0.017 (0.011)	0.006 (0.014)	-0.014 (0.015)	-0.003 (0.011)
Years of schooling	-0.212 (0.204)	-0.082 (0.107)	0.027 (0.128)	-0.006 (0.139)	0.060 (0.104)
Openness index	0.001 (0.004)	0.002 (0.002)	-0.003 (0.003)	0.003 (0.003)	0.001 (0.002)
Polity score	0.236 (0.510)	0.091 (0.243)	0.163 (0.310)	0.474 (0.334)	0.127 (0.256)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.077	0.082	0.196	0.196	0.242
Observations	962	962	962	962	962

* p<0.10, ** p<0.05, *** p<0.010

While the coefficient for the REL index is always negative, the effect is only statistically significant for meteorological (Column (3)) and hydrological (Column (4)) disasters, with no measurable impacts for geophysical (Column (2)) or climatological (Column (5)) events. This can be attributed to the specific features of disasters, as meteorological and hydrological events are more conducive to effective prevention measures.

7. Robustness checks

We conduct several important robustness checks. First, we use lagged REL index scores, as it is likely that it takes some time for national disaster risk management governance policy reforms to become tangible. This approach emphasizes that the economic repercussions of a present-day disaster are significantly influenced by policy changes implemented in the past. In previous work, we have found that the most substantial effects of these processes do not manifest immediately but rather unfold over several years post-implementation (Guerrero and Lacambra 2020).

Table 6 presents five IV estimates of the effect of REL governance on disaster-related economic losses. Column (1) includes the contemporaneous REL index as an explanatory variable. Columns (2) - (5) include the REL index variable with a 1-, 5-, 10-, and 15-year lag, respectively. All specifications include country and time fixed effects. These regressions show that, in fact, improvements in disaster resilience to economic loss take time to consolidate. While an additional point in the contemporaneous REL index leads to a reduction of approximately 4.3% of the total economic losses attributable to disasters, the 1- and 5-year lagged REL coefficients are 6.8% and 6.7%, respectively, a 56-58% increase in magnitude. Beyond a 10-year lag length, however, the effects taper off and are not statistically different from zero.

Table 6. IV estimates of the effect of REL governance on disaster-related economic losses, with lagged variables, pooled sample, 1980-2016

	(1)	(2)	(3)	(4)	(5)
Log(per capita GDP)	-0.657 (3.480)	-0.821 (3.612)	1.131 (2.846)	-1.348 (3.095)	-10.32 (6.984)
Log(per capita GDP) ²	0.042 (0.222)	0.045 (0.230)	-0.088 (0.188)	0.060 (0.200)	0.574 (0.392)
Disaster count	0.164** (0.064)	0.170** (0.062)	0.153** (0.062)	0.144** (0.067)	0.129* (0.067)
Duration of catastrophic disasters	0.004** (0.002)	0.004** (0.002)	0.003** (0.001)	0.003** (0.001)	0.003*** (0.001)
Log(Area)	13.497*** (3.998)	15.943*** (3.872)	16.441*** (2.179)	13.115*** (2.917)	12.718** (5.400)
Log(Exposed infrastructure)	1.660** (0.618)	2.014*** (0.634)	1.374** (0.501)	0.807 (1.580)	1.964 (3.621)
Log(M3/GDP)	0.132 (0.143)	0.179 (0.155)	0.159 (0.150)	0.021 (0.143)	0.025 (0.195)
Size of government	0.019 (0.022)	0.017 (0.025)	0.022 (0.024)	0.032 (0.020)	0.026 (0.041)
Years of schooling	-0.212 (0.276)	-0.169 (0.266)	-0.315 (0.237)	-0.147 (0.311)	-0.398 (0.353)
Openness index	0.001 (0.004)	0.002 (0.004)	0.001 (0.004)	0.002 (0.004)	0.008 (0.006)
Polity score	0.236 (0.399)	0.068 (0.322)	-0.267 (0.511)	-0.015 (0.832)	0.456 (0.737)
REL	-0.043*** (0.012)				
REL(-1)		-0.068*** (0.015)			
REL(-5)			-0.067*** (0.018)		
REL(-10)				-0.032* (0.016)	
REL(-15)					-0.001 (0.047)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.064	0.069	0.054	0.047	0.043
Observations	962	936	832	702	572

* p<0.10, ** p<0.05, *** p<0.010

Our second robustness test considers the possibility that certain disaster risk management public policy elements might contribute more than others to risk resilience. As mentioned earlier, the IGOPP assesses

disaster risk management governance by evaluating 241 indicators distributed in six equally weighted policy reform components. An alternative is to assign different weights to each component, depending on their relative importance. The IDB Disaster Risk Management Group carried out an alternative application method for the IGOPP with a weight structure that reflects composite valuations of the components (IDB 2014). This method relied on a participatory methodology of budget allocation in workshops of experts, followed by a pilot application and adjustment of the weights as a function of the results of the pilot test. Specifically, two participatory workshops were held at the Inter-American Development Bank with a panel of experts to present applicable methodologies and discuss the criteria for allocation of weights. This expert panel was made up of specialists who have worked in areas related to DRM in Latin America, specifically in public policy reform processes (some of whom also participated in defining the indicators that constitute the IGOPP). After the workshops and allocation of weights, pilot tests were carried out in Panama and Peru and the conclusions from these tests were later used to adjust the final version of the weights. Table 7 shows that when the unweighted REL score is replaced by the weighted REL score as an explanatory variable, the IV estimates yield robust, although more conservative, results in the case of disaster-related economic losses. As with the case of the unweighted REL index, only the regressions for the pooled sample as well as those of meteorological and hydrological disasters are statistically significant. In this conservative scenario, an additional point in the weighted REL index leads to a reduction of 1.7% in total economic losses attributable to disasters.

Table 7. IV estimates of the effect of REL governance on disaster-related economic losses, by disaster category, 1980-2016

	(1) Pooled	(2) Geophysical	(3) Meteorological	(4) Hydrological	(5) Climatological
Weighted Disaster Resilience to Economic Loss (WREL)	-0.017* (0.010)	-0.002 (0.003)	-0.006 (0.004)	-0.016** (0.007)	-0.001 (0.005)
Log(per capita GDP)	-0.688 (1.490)	-1.330* (0.705)	0.590 (1.049)	0.863 (0.944)	-0.281 (0.609)
Log(per capita GDP) ²	0.052 (0.089)	0.077* (0.041)	-0.030 (0.063)	-0.037 (0.056)	0.022 (0.036)
Disaster count	0.215*** (0.047)	0.311*** (0.093)	0.328*** (0.070)	0.190*** (0.049)	0.715*** (0.077)
Duration of catastrophic disasters	0.004** (0.002)	0.061*** (0.020)	0.229** (0.092)	0.043*** (0.005)	0.004** (0.002)
Log(Area)	-0.016 (0.071)	0.001 (0.015)	-0.022 (0.028)	0.076* (0.042)	0.004 (0.018)
Log(Exposed infrastructure)	0.236*** (0.063)	0.028* (0.016)	0.216*** (0.061)	0.079 (0.066)	-0.019** (0.008)
Log(M3/GDP)	-0.146 (0.096)	-0.061* (0.035)	-0.032 (0.060)	-0.045 (0.072)	-0.028 (0.035)
Size of government	0.020 (0.020)	0.014** (0.007)	0.016 (0.010)	0.004 (0.011)	0.005 (0.008)
Years of schooling	0.007 (0.083)	0.020 (0.030)	-0.043 (0.034)	-0.025 (0.047)	-0.058** (0.029)
Openness index	-0.001 (0.002)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.001** (0.001)
Polity score	0.522 (0.422)	0.077 (0.123)	0.344* (0.203)	0.797*** (0.224)	0.157 (0.126)
Constant	2.324 (5.823)	5.633** (2.853)	-2.410 (4.137)	-5.448 (3.949)	1.222 (2.553)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.218	0.122	0.35	0.272	0.297
Observations	962	962	962	962	962

* p<0.10, ** p<0.05, *** p<0.010

A prevalent issue within the domain of historical disaster-related economic losses revolves around assessing the potential damage a historical event might incur under contemporary conditions, characterized by present-day exposure levels and pricing dynamics. This issue transcends mere inflation adjustment, requiring a nuanced consideration of adjustments in hazard-exposed assets specific to the location(s) of the disaster. The methodology employed to address this concern is referred to as loss data normalization,

representing the preferred approach to render historical losses comparable to those incurred in the present era. As a third robustness check, we use normalized economic loss data from MunichRe's NatCatSERVICE (2017) to account for any potential increase in local assets and values that would be prone to historical disasters if they reoccurred today.

The effect of disaster resilience to economic loss is robust to the economic loss normalization. When correcting for asset exposure levels, our data show that an additional point in the REL index leads to a reduction of 5.1% in total economic losses attributable to disasters. The increase in impact is expected considering that economic loss estimates have been corrected for asset exposure. As in previous specifications, when we disaggregate based on disaster typologies, the effect is only statistically significant for meteorological (Column (3)) and hydrological (Column (4)) disasters, with no measurable impacts for geophysical (Column (2)) or climatological (Column (5)) events. This may be the case given that countries may have developed better adaptation, risk reduction and disaster preparedness measures to mitigate the impact of geophysical and climatological disasters, such as earthquakes and droughts. These measures could include building codes, early warning systems, and disaster response plans. Consequently, the resilience to economic loss from these types of disasters may be higher, making the coefficients statistically insignificant in the regression model. Furthermore, meteorological and hydrological disasters, such as hurricanes, floods, and storms, often occur with high frequency and severity across LAC. These events can cause widespread damage to infrastructure, agriculture, and livelihoods, leading to significant economic losses. Table 8 summarizes these findings.

Table 8. IV estimates of the effect of REL governance on normalized disaster-related economic losses, by disaster category, 1980-2016

	(1) Pooled	(2) Geophysical	(3) Meteorological	(4) Hydrological	(5) Climatological
Disaster Resilience to Economic Loss (REL)	-0.051*** (0.012)	-0.005 (0.009)	-0.034*** (0.011)	-0.038** (0.014)	-0.015 (0.009)
Log(per capita GDP)	0.187 (3.363)	-2.947 (2.117)	5.759*** (1.611)	-0.390 (2.826)	-1.922 (1.521)
Log(per capita GDP) ²	-0.016 (0.216)	0.167 (0.133)	-0.356*** (0.093)	0.044 (0.177)	0.126 (0.099)
Disaster count	0.180** (0.068)	0.325*** (0.108)	0.314** (0.117)	0.196** (0.083)	0.755*** (0.114)
Duration of catastrophic disasters	0.004** (0.002)	0.076*** (0.024)	0.240** (0.100)	0.047*** (0.005)	0.005** (0.002)
Log(Area)	15.742*** (4.429)	-1.292*** (0.246)	1.680 (1.121)	10.297*** (3.658)	-2.886 (2.070)
Log(Exposed infrastructure)	1.979*** (0.629)	0.243 (0.257)	0.606 (0.632)	1.398** (0.580)	0.101 (0.276)
Log(M3/GDP)	0.117 (0.150)	-0.048* (0.025)	0.055 (0.102)	0.094 (0.105)	0.068 (0.071)
Size of government	0.016 (0.023)	0.018* (0.010)	0.003 (0.012)	-0.021 (0.018)	-0.005 (0.010)
Years of schooling	-0.307 (0.262)	-0.096 (0.150)	0.010 (0.169)	-0.071 (0.157)	0.057 (0.118)
Openness index	0.002 (0.004)	0.002 (0.001)	-0.004 (0.002)	0.003 (0.002)	0.001 (0.001)
Polity score	0.201 (0.436)	0.117 (0.196)	0.119 (0.245)	0.560* (0.296)	0.178 (0.300)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.065	0.073	0.186	0.191	0.229
Observations	962	962	962	962	962

* p<0.10, ** p<0.05, *** p<0.010

A final robustness check addresses the inherent uncertainty in disaster-related economic loss data. Disaster-related data, whether it is human or economic losses, are always estimates, and values may vary significantly depending on the area where the disaster took place, the methodology to assess disaster losses as well as data sources. Disaster loss information is thus inconsistent and subject to accuracy, recording and classification issues, particularly the further one goes back in time. In general, it can be

asserted that large loss events exhibit significant uncertainty in absolute values but comparatively less uncertainty in relative values. Conversely, small loss events demonstrate minimal uncertainty in absolute values but substantial uncertainty in relative values. This phenomenon can be attributed to two primary factors. Firstly, there is a higher quality of information for larger loss events, given the heightened level of general interest. Secondly, the larger and more extensive a loss event, the greater the likelihood that errors in assumptions will balance out during the estimation process, as indicated by the central limit theorem. It is estimated that multi-billion-dollar losses in developed and certain emerging countries typically fall below 10%, whereas errors in losses of just a few million dollars can easily surpass a factor of 2 (Munich Re 2017).

Therefore, we recognize that our reported results stem from the analysis of data prone to noise. It is plausible that this measurement exhibits correlation with certain explanatory variables, making it non-random, thereby potentially introducing bias into the estimations. Consequently, we carried out a Monte Carlo analysis, mirroring the approach taken by Plümper and Neumayer (2009) in their examination of famine-related mortality. The objective was to delve into the impact of measurement error.

To this end, we re-estimate full OLS and IV models (with both country and time fixed effects) for the aggregate economic loss (both unadjusted and normalized) data 1,000 times. Following Plümper and Neumayer (2009), we multiplied the value of economic losses of 15% of the observations by a uniform random number in the interval [0.5, 1.5], which mirrors measurement errors of up to 50%. In Table 9, we present the complete spectrum of coefficients derived from the Monte Carlo study, encompassing the minimum to maximum values. This approach goes beyond reporting only the mean, offering a comprehensive view of the susceptibility of our estimates to measurement error, considering the entire range rather than just the average vulnerability. While measurement error tends to be random on average, it exhibits correlation with the covariates in individual iterations. Examining the Monte Carlo estimates' range allows us to consider not only random but also non-random measurement errors.

As anticipated, the minimum values in the Monte Carlo estimates indicate a more pronounced impact of REL governance, while the maximum values imply a less pronounced effect compared to the mean of the Monte Carlo estimates. Notably, these findings closely align with our primary estimation results, which do

not account for measurement error. Whenever our primary estimations suggest a negative impact of REL governance on economic losses, this conclusion is corroborated by both random (mean estimate) and partially non-random measurement error (minimum to maximum) considered in the Monte Carlo analysis. Simply put, this analysis shows that our results are robust to measurement error in economic losses.

Table 9. Summary statistics of Monte Carlo analysis testing the robustness of REL governance estimates toward measurement error, based on full models with pooled data; 1,000 iterations

	Mean	Std. dev.	Min	Max
OLS	-0.029	0.004	-0.043	-0.017
OLS, normalized losses	-0.040	0.004	-0.055	-0.028
IV	-0.042	0.005	-0.058	-0.026
IV, normalized losses	-0.052	0.005	-0.071	-0.036

8. Conclusion

Disaster risk management governance plays a crucial role in enhancing society's resilience to disasters, and its importance is highlighted by the United Nations Sendai Framework for Disaster Risk Reduction (SFDRR). This paper offers robust evidence that improvements in disaster resilience to economic loss governance mitigate economic losses caused by disasters triggered by natural hazards. This research complements our previous work, where we also showed that improved DRM governance is associated with less mortiferous disaster events (Guerrero Compeán et al. 2017, Guerrero Compeán and Lacambra 2020).

Our research represents a pioneering endeavor to empirically establish a causal relationship between disaster resilience to economic loss governance and economic losses. This study relies on an intricately constructed database of 26 countries for the period 1980-2016 focusing on disaster risk management governance, notably distinguished as the largest dataset of its kind for the Latin America and Caribbean (LAC) region. The significance of our work is underscored by its departure from prior research, as it systematically addresses the critical issue of endogeneity between economic losses and disaster risk management governance—a facet traditionally overlooked in the literature. Moreover, our paper introduces

a novel dimension to the discourse by leveraging a meticulously curated dataset, hitherto unavailable to the public, containing information on economic losses specific to the LAC region. This unprecedented dataset enriches our study and facilitates a more nuanced understanding of the interplay between disaster risk resilience and economic outcomes.

An additional noteworthy contribution lies in our ability to operationalize disaster resilience to economic loss governance, a feat made possible through the application of the Inter-American Development Bank's Index of Governance and Public Policy in Disaster Risk Management (IGOPP). The IGOPP provides a comprehensive and methodologically sound approach to investigating the intricate dynamics between governance structures and economic losses in the context of disaster risk management and allowed us to develop a Disaster Resilience to Economic Loss (REL) governance index, based on the Risk Identification and Risk Reduction components of the IGOPP.

We apply an instrumental-variable regression model that controls for general time trends and unobserved, time-invariant differences across observations. We estimate that a one-point increase in the REL governance index reduces economic losses caused by disasters by 4.3%. We argue that the effect of disaster resilience to economic loss governance is stronger for meteorological and hydrological disasters. Meteorological and hydrological disasters, such as hurricanes, floods, and storms, often have more predictable patterns and can be detected well in advance. Effective REL governance can capitalize on this predictability by implementing robust regulation to reduce infrastructure vulnerabilities and support the improvement of human settlements, as well as disaster risk reduction regulatory frameworks across sectors. This might lead to a more noticeable impact on reducing economic losses compared to geophysical events like earthquakes, which can be less predictable. Similarly, governance structures may be more successful in implementing adaptation strategies for meteorological and hydrological events. For example, investments in resilient infrastructure, land-use planning, and community awareness programs may have a more immediate and tangible impact on reducing vulnerabilities to floods or hurricanes compared to geophysical events, where the emphasis might be on building codes and construction practices.

Our results are robust to several changes in model specification. First, our analysis finds that significant lagged effects can be detected up until 10 years after REL governance policy reforms took place. Second,

an adjusted measurement of economic losses and an alternative methodological approach to the operationalization of the IGOPP indicate that estimated impacts are consistently significant and that REL governance improvements do reduce economic damage caused by natural hazards. Third, we tackle the issue of uncertainty inherent in economic loss data through a Monte Carlo analysis. Despite the introduction of considerable uncertainty through this simulation, our findings consistently reveal a robust and statistically significant negative relationship between REL governance and economic losses, underscoring the validity and reliability of our results, emphasizing that even when confronted with a notable degree of measurement error in economic loss data, the fundamental negative association between REL governance and economic losses persists.

While our research indicates the substantial significance of REL governance in mitigating economic losses, it also sheds light on a concerning reality: REL governance levels across the region are at an incipient stage. According to the Inter-American Development Bank's RiskMonitor, the regional average score for the IGOPP's Risk Identification and Risk Reduction components stands at 31.2% and 39.8%, respectively. This figure underscores the relatively incipient state of REL governance within the region, emphasizing the imperative for concerted efforts and interventions to enhance and strengthen governance structures for more effective disaster risk management, particularly for risk identification and risk reduction.

Several policy recommendations to enhance the effectiveness of risk identification and risk reduction and, thus, REL efforts should be considered (IDB 2020). First, establish the notion of acceptable risk with respect to relevant natural hazards. Acceptable risk should be understood as the level of loss or affectation within a period of time, which is considered admissible to determine the minimum demands or safety requirements, for protection and planning purposes, in the face of possible dangerous phenomena. In general, countries must have regulations that establish safety levels for construction and occupation of the territory that must be complied with, taking into account parameters of intensity of phenomena associated with periods of return or the annual frequency of excess losses or effects for at least two threats. Second, establish national regulations that require public entities to reduce the vulnerability of essential, indispensable buildings or critical infrastructure through reinforcement or replacement measures. Examples of "essential", "indispensable" or "critical infrastructure" buildings are hospitals, schools, fire or police

stations, emergency management centers and facilities for communications, power generation and supply, etc. Because of their strategic nature and the importance of the services they provide, they should not be rendered useless or collapse in the event of a disaster. Third, countries should recognize as good practice the consideration of measures to reduce the risk that is generated during the construction stage of infrastructure projects due to the effects of the work itself and that may affect third parties. For example, in the construction of a hydroelectric dam, there is the risk of a flood, for which a series of risk reduction measures should have been previously considered not only to protect the infrastructure under construction, but also the population, economic activities and infrastructure located downstream whose level of risk could increase during the construction phase of the infrastructure due to the characteristics of the work and its construction arrangements. Fourth, enhance national standards and codes for the design and construction of buildings that collect the results of risk analysis and translate them into mandatory rules or precepts for public or private projects, in order to provide them with sufficient resistance to withstand the action of forces caused by dangerous natural phenomena such as earthquakes or winds and the significant economic losses attributable to these hazards. Fifth, it is considered good practice that a legal framework for the relocation of human settlements located in risk areas is in place in order to reduce the likelihood of loss of life and property.

While disasters are inevitable, we possess a set of policy tools and a wealth of empirical evidence supporting their efficacy. By leveraging these resources, governments can work towards minimizing the magnitude of both human and economic losses in the future. These policy tools encompass a spectrum of measures, including robust resilience to economic loss governance, such as national regulations to reduce vulnerabilities of infrastructure.

The empirical evidence at our disposal underscores that proactive disaster risk management significantly contributes to mitigating the impact of disasters on communities and economies. Through the implementation of evidence-based policies, we have the potential to enhance resilience, reduce vulnerabilities, and foster sustainable development. By integrating these insights into governance structures and decision-making processes, governments can strive to create environments where the well-being of communities worldwide is safeguarded, even in the face of disasters triggered by natural hazards.

Ultimately, the collective effort to employ these policy tools is an investment in the long-term prosperity and sustainability of societies globally.

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