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Climate Change and Extreme Weather Events in Latin America:

An Exposure Index

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Abstract

Climate change is changing the frequency and intensity of Extreme Weather Events (EWEs), particularly in poor developing countries, and the international community is increasingly suggesting the design of adaptation funds to resolve this situation. Measures of vulnerability and exposure to EWEs are a critical instrument in guaranteeing a transparent, efficient and equitable allocation process in these funds. Latin American countries, which contribute little to climate change but are hard-hit by EWEs, urgently need new indicators to back up their claims for financial and technical assistance. Using DesInventar data, the paper develops an innovative Disaster Exposure Index (DEI) that encompasses many disasters' impacts. DEI calculations indicate an unexpected scenario where some regions usually considered resilient are found to be exposed. The results call for further development of regional indicators to facilitate the international, national and sub-national allocation of adaptation funds.

JEL classifications: F64, H12, H84
Keywords: Natural disasters, Climate change, Index, Latin America, DesInventar

Contents

1. Introduction

Climate change is increasing the frequency and intensity of (EWEs). Severe drought lurks behind the Darfur conflict (Faris, 2007); a rising sea level has combined with subsidence and cyclone activity to drive thousands of people off islands in the Sundarbans of India and Bangladesh (Sengupta, 2007); a World Meteorological Organization (WMO) report issued in August, 2007, linked global warming to unprecedented rainfall and flooding in South Asia and China (WMO, 2007). Warmer seas and greater atmospheric moisture seem to have increased the power of hurricanes, magnifying their destructive coastal impacts in Central America, the Caribbean, East Asia and South Asia (Emmanuel, 2005; Webster et al., 2006). In a possible indicator of this trend, the year 2007 witnessed the first documented hurricane landfalls in Brazil and the Arabian Sea (WMO, 2007). There has been a notable surge of extremely damaging weather in Pakistan (New York Times, 2010a), Russia (RIA Novosti, 2010), China (New York Times, 2010b) and elsewhere. Latin America is not isolated in this context. Extreme rainfall episodes have caused disasters in parts of South America, with hundreds to thousands of fatalities in mudslides and landslides (Lyon, 2003). Climatic disasters account for the majority of natural disasters in Central America, with most of its territory located in tropical and equatorial areas. Recent EWEs included several floods in Argentina (2007, 2012), two hurricanes impacted Mexico (2009), Tropical Storm Matthew (2010) in Venezuela and a series of floods in Colombia (2011).

Countries are not on a level playing field when facing EWEs. Extreme weather might produce no effect if it occurs in deserted areas, while elsewhere it may entail deaths, missing persons and economic losses. Only when events translate into impacts do they become disasters. Confluent elements determine countries predisposition to suffer disasters, ranging from the probability that the event will happen to the exposure of population and infrastructure and the ability to adapt and resist hazards. All these elements have been defined as vulnerability (Blaikie et al., 1994). These factors interact with each other: successful adaptation policies reduce exposure; population relocation to safer locations reduces their risk. Dynamics also play an important role: economic growth can generate resources to build better buildings and design preventive measures. As debates continue over how to deal with climate change (Broome, 2012), countries should prepare themselves for the destructive climate events to come.

Developing countries, which contribute little to climate change but are hit hard by extreme events, face a challenging scenario. From 1987 to 1998, the annual number of climate-related disasters averaged 195. From 2000 to 2006, the average was 365, representing an increase of 87 percent. About three-quarters of all disasters were triggered by weather-related events during the 1990s, floods and drought being among the most prominent causes. More than 95 per cent of all deaths caused by natural disasters occur in developing countries, and losses due to natural disasters are 20 times greater (as a percentage of GDP) in developing countries than in industrialized countries (UNFCCC, 2008). Poverty, inequality, lack of resources, poor infrastructure and corruption undermine efforts to improve resilience to disasters, and the international community is increasingly suggesting the need to design adaptation funds to resolve this situation (UNFCCC, 2008). The World Bank (2009) puts the funding required for adaptation in developing countries at $75–100 billion a year. United Nations Development Programme estimates (UNDP, 2007) are of a similar order of magnitude, while the UN Framework Convention on Climate Change (UNFCCC 2008) expects adaptation costs of $27–67 billion a year in developing countries and $44–166 billion a year worldwide.

A critical point in adaptation funds is to decide how they should be distributed (Barr, Fankhauser and Hamilton, 2010). Vulnerability measures can provide an objective way in which countries in need of financial assistance might provide evidence of their situation, and indexes are already available to evaluate countries' exposure to climate change. Those indexes have focused on human and economic losses (Nazmul, 2001; Peduzzi et al., 2009; IDB, 2010; Wheeler, 2011) and environmental sustainability (Nazmul, 2001; SOPAC, 2004). They consider however, only a limited set of impact indicators (Peduzzi et al., 2009), are based on country-level data sets (Nazmul, 2001) or deal only marginally with disasters related with climate change (SOPAC, 2004).

In order to improve the assessment of climate-change risks and therefore the distribution of adaptation funds, this paper designs a novel measure of exposure. Based on the methodology traditionally used in UNDP's Human Development Index or HDI (UNDP, 2006), a Disaster Exposure Index (DEI) was calculated using the Disaster Inventory System (DesInventar) data set. This index condenses the impact of disasters on human lives, economies and infrastructure into a unique number to assess countries' exposure to EWEs.

The discussion starts with a description of the data sources available on natural disasters in Section 2. Section 3 includes an assessment of indexes available and a brief description of DEI methodology; further details are located in the Annex. Section 4 is divided into two parts. The first analyzes disasters distribution in Latin America and the impact of disasters on different countries, and the second is dedicated to scenario projected by the DEI. Section 5 summarizes the paper and suggests possibilities for future developments in disaster indexes and their use.

2. Data on Disasters

Almost all recent empirical work relies on the Emergency Events Database or EM-DAT (Kahn, 2005; Cavallo, Powell and Becerra, 2010; United Nations and World Bank, 2010). EM-DAT is maintained by the Center for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvain, Belgium (http://emdat.be/). It is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutions and press agencies. Types of disasters can be hydro-meteorological (floods, wave surges, storms droughts, landslides and avalanches), geophysical (earthquakes, tsunamis and volcanic eruptions) and biological (epidemics and insect infestations). Impacts reported include direct damages (e.g., damage to infrastructure, crops and housing), number of people killed and otherwise affected and dollar amount of direct damages of each disaster. Its main disadvantage is that data are available only at the country level.

Few authors use other data sources. Most notable are those that estimate the impact of storms/hurricanes. These papers use data on storm intensity, typically measured by the United States (U.S.) National Oceanic and Atmospheric Administration, NOAA (e.g., Yang, 2008). This dataset provides normalized damages (i.e., estimates of the damages that would occur if storms from the past made landfall under another year's societal and economic conditions) for mainland U.S. hurricanes from 1900-2005. An alternative but similar source that is less extensive, and only parts of which are publicly available, is the Munich Re dataset, available at http://mrnathan.munichre.com/. A similar data collection effort with similar coverage but more limited access is maintained by another reinsurer, Swiss Re. For an analytical review of selected data sets on natural disasters see Tschoegl et al. (2006).

2.1 DesInventar

In an effort harmonize the data on natural disaster in Latin America and the Caribbean, Asia and Africa, the Network for Social Studies on Disaster Prevention in Latin America (La Red) began developing the Inventory System of the Effects of Disasters (DesInventar) in 1994. Containing records of all major and medium disasters occurred in most countries in Latin-America for the last 40 years, DesInventar is one of the most comprehensive regional data sources available.

Currently DesInventar maintains approximately 23 national-level natural and technological disaster databases. Based on these data, the Research Department (RES) of the Inter-American Development Bank (IDB) has constructed a dataset for Latin America and Caribbean countries: Argentina, Bolivia, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago and Venezuela.[1] It contains data on 64 types of events, with their 71 different causes, including meteorological, geological and human-related events. Registries are monthly from years 1530 to 2011, although most observations are from the last 40 years.[2] In geographical terms, data are recorded at different subnational levels, including cities and towns.

DesInventar uses a special criterion to define an event. It considers an event as a "phenomenon—natural, socio-natural or technological—which acts as a detonator of adverse effects on human lives, health, and/or economic or social infrastructure in a community" (DesInventar, 2009). An event is different from a disaster. An event may trigger multiple disasters as well as affecting different geographical units. This means that the statistics DesInventar records differ from statistics which use the traditional definition of disaster, but only in regard to the number of events rather than effects and damages. It should also be noted that DesInventar only considers cause to be the phenomenon that immediately caused the event and does not take indirect causation into account.

The registration of disasters impacts presents several issues. Number of deaths, persons injured and houses destroyed are common in databases of this type, but monetary estimations of infrastructure damage (in local currency units and USD) are highly imprecise (Tschoegl, 2006). On the other hand, as the database includes small and medium-scale disasters (not represented in larger-scale databases), it shows an exaggerated numbers of people affected. Also, newspapers are the main data source,[3] raising doubts on the accuracy of damages measurement (IFRC, 2005).

Certain factors, moreover, limit how DesInventar can be used in international comparisons. National-level databases are developed by several agencies including national

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[1] A critical Latin American country missing is Brazil.

[2] The total countries and events frequencies available in DesInventar can be seen in Table A1.

[3] For details consult Table A2.

governments, international organizations, universities, scientific organizations and Non-Governmental Organizations (NGOs). Once data are obtained they are verified nationally for consistency. Shared definitions are used for some key hazards, while for others local specificity is more important. This lack of standardization in data processing and the many organizations involved makes it difficult to assert how comparable events are across countries.

Despite these caveats, DesInventar is one of the best data sources of disasters for Latin-America. It has registries for more years, geographical disaggregation, types of disasters and impact records than any other source available for the region. With clarifications and improvements in the methodology used in its construction, it could be much more broadly used.

3. Measuring Exposure and Vulnerability

EWEs can occur in a variety of places, but only when they produce an impact on human life are they defined as disasters. What factors explain which regions are more prone to suffer disasters have been the main concern in the literature on climate change and natural disasters (Nazmul, 2004; Vincent, 2004; Adger et al., 2004; Thow and de Blois, 2008). In this discussion, vulnerability has emerged as the main concept of interest.

Vulnerability is the ability to anticipate, resist, cope with and respond to a hazard (Blaikie et al., 1994). This definition has led to a wide range of focuses, from disaster risk management (IPCC, 2012; La Red, 2012) to assessment of disasters impacts and coping (World Bank, 2010). Detailed research has been undertaken for specific types of disasters (Besley and Burgess, 2002; Anbarci, Escaleras and Register, 2005; Cavallo, Powell and Becerra, 2010), but both climate change and disasters can affect many aspects of human lives (deaths, economy, infrastructure) and natural environment (forests, water, animals, soils). Several indexes have been developed to encompass these impacts.

3.1 Indexes of Climate Change and Natural Disasters

In the last 10 years several different indexes have been devised to measure environment vulnerability to climate change. The major ones are the Environmental Sustainability Index (ESI), followed by the Environmental Performance Index (EPI) and the Environmental Vulnerability Index (EVI). The EVI, the broadest index, aims to measure how the environment is exposed to different threats: human activities, climate change and natural disasters. ESI and EPI are meant mainly for environmental sustainability, only marginally dealing with climate change.

The EVI, developed by the South Pacific Applied Geoscience Commission (SOPAC) and the United Nations Environment Programme (UNEP), is based on 50 indicators to estimate the vulnerability of a country's environment to future shocks. Countries are categorized into five vulnerability groups: extremely vulnerable, highly vulnerable, vulnerable, at risk and resilient. The EVI also includes seven policy-relevant sub-indices, including aspects of vulnerability to climate change, exposure to natural disasters, human health, agriculture and fisheries, water resources, and desertification and biodiversity. EVI does not, however, address the vulnerability of social, cultural or economic systems. The environment it considers includes only those biophysical systems that can be sustained without direct and/or continuing human support, while human impacts are a key issue in this paper.

One index that measures disasters' impact on human life is the Disaster Risk Index (DRI). Developed by the United Nations Development Program (UNDP, 2004), the DRI enables the calculation of the average risk of death per country in large and medium-scale disasters associated with earthquakes, tropical cyclones and floods. It also allows the identification of a number of socio-economic and environmental variables that are correlated with risk of death and which may point to causal processes of disaster risk. In the DRI, countries are indexed for each hazard type according to their degree of physical exposure, their degree of relative vulnerability and their degree of risk. But the risk of death is only one facet of overall disaster loss and often not the most significant. Also, the DRI calculation is based on an econometric model, a method not easily replicable.

The most complete and recent measures for Latin America are found in IDB (2010), where four indexes were estimated:

- *Disaster Deficit Index* (DDI): Measures country risk from a macroeconomic and financial perspective according to possible catastrophic events. It requires the estimation of critical impacts during a given period of exposure, as well as the country's financial ability to cope with the situation. Uses data from the Economic Commission for Latin America and the Caribbean (ECLAC) and the IADB.

- *Local Disaster Index* (LDI): Identifies the social and environmental risks resulting from more frequently recurring lower-level events. Includes small-scale (in terms of their impact) landslides, avalanches, flooding, forest fires and droughts as well as small earthquakes, hurricanes and volcanic eruptions. Uses DesInventar data.
- *Prevalent Vulnerability Index* (PVI): Made up of a series of indicators that characterize prevalent vulnerability conditions reflected in exposure-prone areas, socioeconomic weaknesses and lack of social resilience in general. Uses a variety of data sources.
- *Risk Management Index* (RMI): Brings together a group of indicators that measure a country's risk management performance. These indicators reflect the organizational, development, capacity and institutional actions taken to reduce vulnerability and losses, to prepare for crisis and to recover efficiently from disasters. Authors used their own indicators.

Indexes developed until now provide a picture of the scenario countries face in a world affected by climate change. All are useful tools to policymakers to facilitate risk management decisions, but several issues render these measures unsuitable for assessing countries' exposure to EWEs.

First, the measures do not deal specifically with EWEs. Some consider climate-related events, but it is in general impossible to disentangle what type of disaster is behind the index. For example, the LDI (IDB, 2010) included landslides, avalanches, flooding, forest fires and droughts, as well as earthquakes, hurricanes and volcanic eruptions, but it is not possible to differentiate among types of disasters and evaluate their degree of relevance.

Second, the types of impacts evaluated do not convey the full human impact of disasters. Efforts have focused on natural environment vulnerability (SOPAC, 2004) without consideration of human lives, a factor highly relevant to policymakers. Of those that consider human impact, like the DRI (Peduzzi et al., 2009) and LDI (IDB, 2010), they included just a few variables.

Third, the measures' geographic disaggregation is insufficient. Most authors have used country-level datasets, an administrative level adequate to provide an overall international picture. But disasters depend critically on location. Country-level indicators can be appropriate for relatively small countries, such as Nicaragua and Guatemala, but for geographically large countries (e.g., Argentina, Peru, Colombia) measures at a lower level of disaggregation can provide critical input for allocation of funds to subnational areas at risk.

These problems call for the development of a new type of measure of exposure to EWEs.

3.2 The Disaster Exposure Index (DEI)

In this paper I present an innovative, flexible and simple measure: the Disaster Exposure Index (DEI). Including only EWEs and using most impact indicators available in DesInventar, the DEI classifies countries according to the relative human and physical impact of disasters. The DEI is decomposable by type of disaster and impact, allowing the observation of the elements behind the index value. In addition, the DEI was calculated at country and subnational levels, something impossible with other datasets, and this index’s simplicity of calculus and wide availability of indicators used allows its updating, replication and use in other data sources. These features make the DEI a reliable instrument for assess the exposure to EWEs and a powerful argument in the allocation of adaptation funds.

One clarification is necessary at this: exposure is not the same as vulnerability. Instead, it is the immediate impact of a disaster.[4] As explained above, vulnerability is the major concern in the literature, but it is a much broader concept in which exposure is just one element. In this sense the DEI should be understood as an indicator of the losses directly related with disasters, a necessary but not sufficient condition for vulnerability. One country could suffer great losses after a disaster (high exposure) but recover quickly afterward (low vulnerability). Following is brief description of the methodology.

3.2.1 Sub-Indexes

The construction of an index consists of several steps. First is the selection of the regions to rank and second, the selection of a set of indicators for each region. Finally, the method of calculation is chosen.

The regions ranked here are Latin American countries and their subnational regions. The same impact indicators have been chosen for all countries, discarding only monetary losses because of the lack of precision in their estimation. The indicators chosen are categorized as

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[4] This is not the definition used by other authors that define exposure as the elements (people, livelihoods; environmental services and resources; infrastructure) that are subject of damage in case of an extreme event (IPCC, 2007, 2012; UNDP, 2004).

Human and Physical. Human indicators include deaths, missing, wounded and sick, victims affected, evacuees and persons relocated. Physical indicators are divided into two major groups: houses and infrastructure. The former refers to destroyed and affected houses, while the latter is a broader category including effects on routes, crops and wood, livestock, education and health centers. The last category is a set of dummy variables indicating impacts on certain types of infrastructure. Sub-indexes were calculated for different sets of indicators according to the type of impact:

- Human impact (D1):
    - Direct
        - D1.1: Deaths, Missing, Wounded and sick.
    - Indirect
        - D1.2: Victims, Affected, Evacuees, Relocated.
- Physical impact (D2):
    - Houses
        - D2.1: Destroyed, Affected
    - Infrastructure
        - D2.2.1ND: Routes.
        - D2.2.1D: Transport, Communications, Aqueduct, Sewerage.
    - Capital
        - Economy
            - D2.2.2ND: Crops and wood, Livestock
            - D2.2.2D: Agriculture and livestock, Energy, Industry
        - Services
            - D2.2.3ND: Education, Health centers
            - D2.2.3D: Education, Aid organization, Health

Finally, DEI was calculated as the average of all sub-indexes. The previous procedure was run for each disaster, country and subnational region. In order to provide a single DEI number for each country, DEI across all disasters was aggregated using as weight the disaster probability.[5]

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[5] Further details on the methodology can be found in the Annex.

Impact per event was additionally used as indicator. For example, if the total number of deaths was 1,000 in 50 floods, then 20 deaths per event was used instead of 1,000. This indicator was chosen for many reasons. First, per event impact limits “registries” effects. Since geographically big, wealthy and/or more populated regions tend to register more events, an index based on simple aggregates measures would be highly correlated with these variables without showing the exposure of smaller and/or poorer countries. Second, the impact per event indicator is easy to calculate. Other types of adjustments based on population or GDP require data from third-party sources different than DesInventar. In many cases this can be a challenging task, especially in subnational cases and for long time series. Finally, the impact per event indicator was chosen for its simplicity, as policy makers are primarily interested in how each event produces large (or small) negative effects. Other adjusted measures can be technically creative, but their relevance can be difficult to comprehend, and they may possibly mix exposure with other vulnerability components such as coping.[6]

3.2.2 From Causes and Events to Climate Change-Related Disasters

The types of disasters registered in DesInventar are extensive, including human (accidents, fires, pollution), climate (hurricanes, storms, heat waves) and geological (earthquakes). I am concerned with disasters that are presumed to be related with climate change (UN and WB, 2010; Thow and de Blois, 2008; IPCC, 2012), such as landslides caused by rainfalls but not by earthquakes. Under this criterion I selected only causes related with climate and classified them into four categories: atmospheric conditions, drought, flooding and hurricanes. Nonetheless, many types of disasters fell under these categories. To simplify the analysis I further categorized seven kinds of disasters: flooding, rainfall and storms, landslides, hurricanes, epidemics, fires and droughts.[7] The analysis was exclusively made for these events; to be called EWEs or simply disasters.

3.2.3 Methodology

The methodology chosen is based on the one used to calculate the HDI in UNDP (2006). This method was chosen for three reasons. First, it can be easily replicated by other authors. Second,

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[6] For robustness, population, GDP and GDP per capita adjusted versions where calculated. They provided no valuable information compared with the per event DEI version. Discussion of this exercise has been deferred to the Annex.

[7] Details about the events and causes behind these disasters definitions can be found in Table A3.

the method permits aggregation of any number of impact indicators. Third, the resulting index can be decomposed by indicators, sub-indexes and types of disasters; that is, it is possible to observe what is “behind” index values, such as number of deaths or more houses destroyed. Is the region more exposed, for example, to floods or landslides?

Under the HDI method, the first step to construct the index is to normalize indicators’ values. Indicators vary in units and scales, so in order to obtain figures which are free from the units and also to standardize their values they are transformed so that they all lie between 0 and 1. The standardized indicators are then arithmetically averaged to obtain each of the sub-indexes, and the DEI for each disaster is the result of averaging all sub-indexes. DEIs for countries (and subnational areas) were calculated by weighing each disaster-DEI by the probability of the disaster.[8]

A final standardization was made to have DEI values between 0 and 1, where 1 is the most exposed area. Exposure categories were defined in the following way:

- *Highly exposed:* DEI from 0.8 to 1.0.
- *Exposed:* DEI from 0.6 to 0.8.
- *Medium exposure:* DEI from 0.4 to 0.6.
- *Not exposed:* DEI from 0.2 to 0.4.
- *Covered:* DEI from 0 to 0.2.

4. Disasters in Latin America

Before the results are presented, a note on the years and countries studied is in order. Although data in DesInventar go back as far as 1700, most countries’ registries start in 1970, so analysis was undertaken from this year to the latest date with data available (in most cases around 2010). On the other hand, information for Haiti refers only to the 2010 earthquake, not an event related with climate change; so it was discarded. Nicaragua was also not considered, as data refer only to 2008’s Hurricane Mitch, an extreme event that produced major losses (reaching 1 billion 2008 USD[9]), rendering impact values for this country too large and biasing the exposure analysis based on the DEI.

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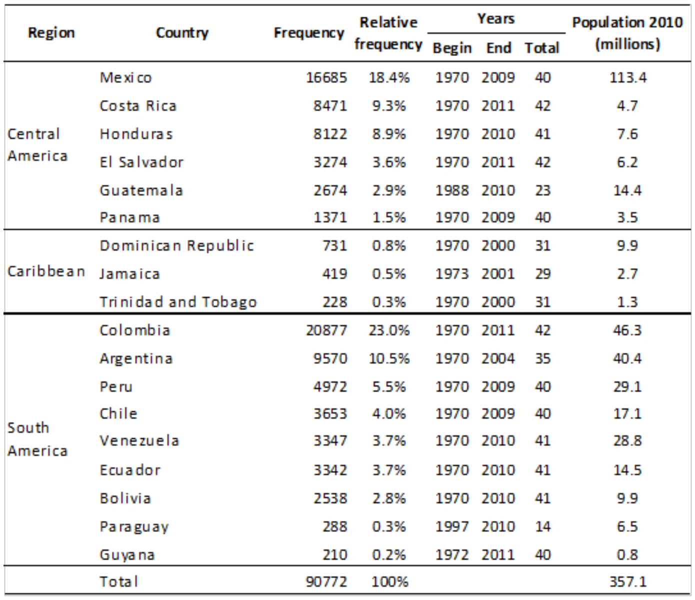
[8] This probability was approximated dividing the number of events (flooding, landslides) in the total number of disasters. Details can be found in the Annex.

[9] Estimations from NOAA, http://www.ncdc.noaa.gov/oa/reports/mitch/mitch.html

The frequency of disasters is highly related with countries' populations (Table 1). Likewise, the regional distribution of population is very similar to that of disasters: 45 percent of disasters occur in Central America[10] (42 percent of population), 1.5 percent of disasters in the Caribbean (4 percent of population) and 54 percent of disasters in South America (54 percent of population). Highly populated countries such as Colombia and Mexico are those with the highest share of disasters (23 percent and 18 percent, respectively). Much less populated countries that are nonetheless likely to be exposed to natural disasters—the Dominican Republic, Jamaica and Trinidad and Tobago—are much less represented. This is no surprise, as the presence of population is a necessary condition for a disaster to occur.

Most countries have disasters registries for over 40 years. Exceptions are Paraguay (14 years), Guatemala (23), Jamaica (29), the Dominican Republic (31), Trinidad and Tobago (31) and Argentina (35). This lack of homogeneous data might underestimate exposure if some disasters were not registered. Caution is advised.

Table 1. Distribution of Disasters



Region	Country	Frequency	Relative frequency	Years			Population 2010 (millions)
				Begin	End	Total	
Central America	Mexico	16685	18.4%	1970	2009	40	113.4
	Costa Rica	8471	9.3%	1970	2011	42	4.7
	Honduras	8122	8.9%	1970	2010	41	7.6
	El Salvador	3274	3.6%	1970	2011	42	6.2
	Guatemala	2674	2.9%	1988	2010	23	14.4
	Panama	1371	1.5%	1970	2009	40	3.5
Caribbean	Dominican Republic	731	0.8%	1970	2000	31	9.9
	Jamaica	419	0.5%	1973	2001	29	2.7
	Trinidad and Tobago	228	0.3%	1970	2000	31	1.3
South America	Colombia	20877	23.0%	1970	2011	42	46.3
	Argentina	9570	10.5%	1970	2004	35	40.4
	Peru	4972	5.5%	1970	2009	40	29.1
	Chile	3653	4.0%	1970	2009	40	17.1
	Venezuela	3347	3.7%	1970	2010	41	28.8
	Ecuador	3342	3.7%	1970	2010	41	14.5
	Bolivia	2538	2.8%	1970	2010	41	9.9
	Paraguay	288	0.3%	1997	2010	14	6.5
	Guyana	210	0.2%	1972	2011	40	0.8
	Total	90772	100%				357.1

Source: Author's calculations based on DesInventar.

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[10] Mexico is included in Central America.

Table 2. Distribution of Natural Disasters distribution (1970-2011)

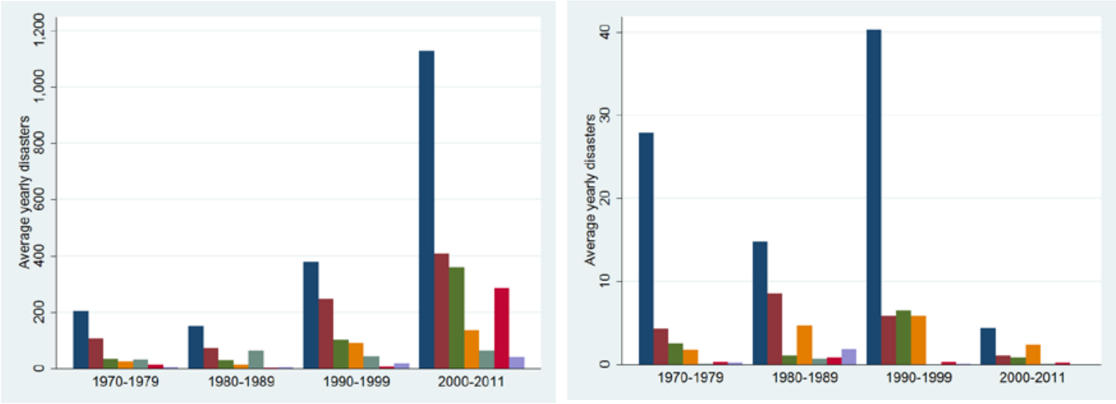
Disaster	Frequency	Relative frequency
Floodings	45,030	49.6%
Rainfalls&storms	17,762	19.6%
Landslides	13,102	14.4%
Hurricanes	6,713	7.4%
Droughts	3,288	3.6%
Epidemics	3,261	3.6%
Fires	1,616	1.8%
Total	90,772	100%

Source: Author's calculations based on DesInventar.

In line with previous observations (WB and UN, 2010), Flooding, Rainfalls and Storms and Landslides have been the predominant disasters in the region (Table 2). These represent more than 80 percent of total disasters, with Flooding alone accounting for almost 50 percent. The other four types of disasters, Hurricanes, Droughts, Epidemics and Fires, are much less frequent but likely to be equally destructive.

Flooding has been the most frequent disaster for the last 40 years (Figure 1). In Central America yearly frequency of all disasters increased, with a great jump in 2000-2011; the same occurred in South America, although changes there have not been so drastic. In both regions Flooding has been, by far, the most recurrent disaster, followed by Rainfalls and Storms; only recently have Landslides become relevant. The Caribbean shows a particular pattern in which the yearly frequency of Flooding dropped drastically in 2000-2011; it had previously been the main disaster. As Caribbean countries have usually been classified as vulnerable countries, one likely explanation for this is that events in that region are less recurring but of higher intensity.

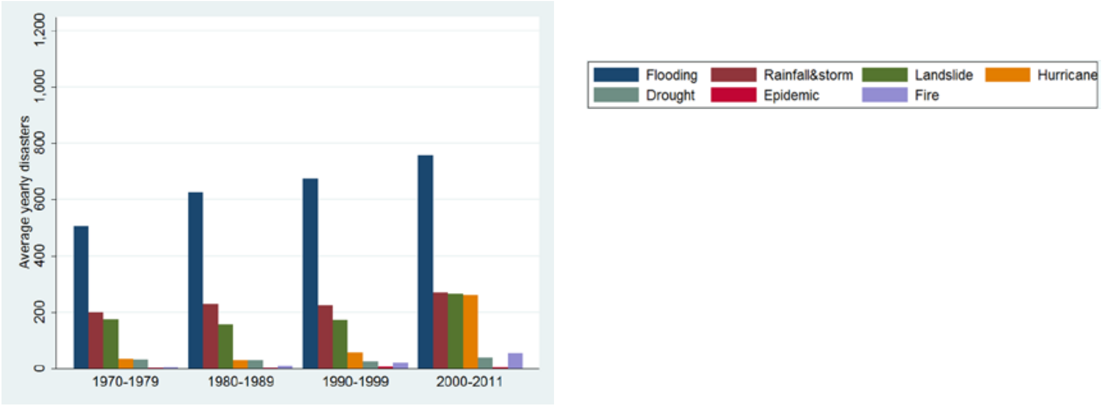
Figure 1. Average Yearly Disasters by Region and Decade (1970-2011)



(a) Central America

(b) Caribbean

(c) South America



Source: Author's calculations based on DesInventar.

Table 3. Frequency of Disasters by Country and Type of Disaster

Region	Country	Floodings	Rainfall&storms	Landslides	Other	Total
Central America	Costa Rica	66%	2%	23%	8%	100%
	El Salvador	51%	9%	26%	14%	100%
	Guatemala	40%	29%	28%	3%	100%
	Honduras	33%	6%	6%	55%	100%
	Mexico	40%	38%	6%	16%	100%
	Panama	62%	9%	17%	12%	100%
Caribbean	Dominican Republic	63%	18%	3%	16%	100%
	Jamaica	57%	12%	14%	17%	100%
	Trinidad and Tobago	78%	7%	12%	4%	100%
South America	Argentina	62%	26%	0%	12%	100%
	Bolivia	62%	15%	11%	12%	100%
	Chile	20%	75%	4%	1%	100%
	Colombia	50%	7%	24%	19%	100%
	Ecuador	50%	19%	27%	4%	100%
	Guyana	76%	13%	0%	11%	100%
	Paraguay	16%	65%	0%	18%	100%
	Peru	66%	20%	10%	3%	100%
	Venezuela	53%	12%	27%	8%	100%
	Total	50%	20%	14%	16%	100%

Source: Author's calculations based on DesInventar.

Disasters distribution by countries follows the aggregate pattern (Table 3). For almost all countries, with the exception of Chile and Paraguay, Flooding is the most recurrent disaster. Rainfall and storm is also the second most important disaster, although Landslides are more important in Honduras, Panama, Jamaica, Trinidad and Tobago, Colombia, Ecuador and Venezuela. Other disasters are less frequent, but in Honduras 55 percent of disasters were other than Floodings, Rainfall and Storms or Landslides (mainly Epidemics[11]).

The distribution of disasters distribution at sub-national levels indicates a close relation with population (Map 1). Considering the three main disasters in the region, disasters tend to concentrate near countries capitals. This is clear in Argentina, Bolivia, Venezuela, Colombia and Panama. The exception is Mexico were most disasters are located in the southeast while the capital is located at the center of the country; probably because hurricanes tend to hit much more this part of the country.

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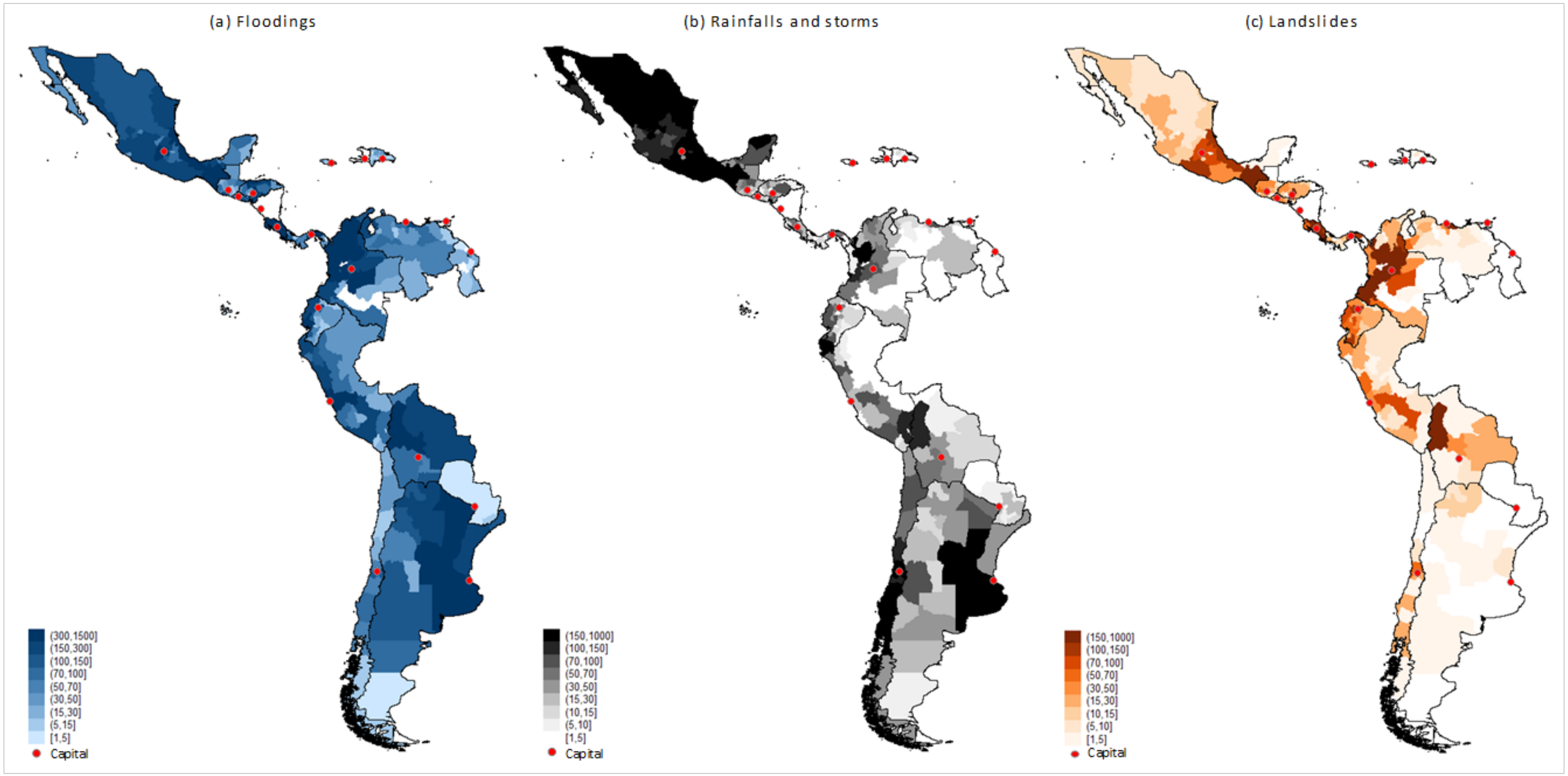
[11] DesInventar data indicates that Honduras has suffered an increase in epidemic episodes in the last 10 years, most caused by rainfalls.

Map 1. Geographic Distribution of Main Natural Disasters at Subnational Levels



(a) Floodings

(b) Rainfalls and storms

(c) Landslides

Source: Author's calculations based on DesInventar.

Although events' frequencies indicate the likelihood of disasters' occurrence, but the intensity of disasters is a clearer indicator of the destruction they will cause. Disasters' impacts are aligned with their frequencies, although not in all cases (Tables 4 and 5). For example, Honduras suffered 2,666 floods and had 10,202 deaths; Colombia, on the other hand, had 10,444 floods and only 2,731 deaths. To balance the effects of overall aggregate impacts with the number of events the impact per event was calculated, as discussed above; per event impacts provide valuable information on disasters' effects. Rainfall and storm are infrequent in Honduras, but more than 2 people died in each event, much more than in any other country. Among common disasters, Landslides in Mexico destroyed more than 10 houses in each event.

As explained above, many impact indicators have been analyzed, and describing all of them would make the exposition unnecessarily extensive and repetitive. DEI has used these impact indicators in its construction, and its decomposability feature permits the observation of all different impacts at the same time.

Table 4. Deaths by Disaster and Country (1970-2010)

Region	Country	Total				By event			
		Floodings	Rainfall&storms	Landslides	Others	Floodings	Rainfall&storms	Landslides	Others
Central America	Costa Rica	129	16	84	0	0.02	0.08	0.04	0.00
	El Salvador	717	165	634	31	0.43	0.55	0.76	0.07
	Guatemala	177	735	534	6	0.17	0.96	0.70	0.07
	Honduras	10202	1024	110	7341	3.83	2.10	0.22	1.64
	Mexico	3611	8571	2130	1344	0.54	1.34	2.14	0.52
	Panama	77	45	18	25	0.09	0.37	0.08	0.15
Caribbean	Dominican Republic	202	42	24	4	0.44	0.32	1.04	0.03
	Jamaica	90	11	1	113	0.38	0.21	0.02	1.59
	Trinidad and Tobago	17	0	0	0	0.10	0.00	0.00	0.00
South America	Argentina	755	384	10	202	0.13	0.16	0.22	0.18
	Bolivia	552	161	231	97	0.35	0.42	0.82	0.31
	Chile	242	283	69	7	0.34	0.10	0.43	0.16
	Colombia	2731	416	3564	157	0.26	0.29	0.72	0.04
	Ecuador	882	79	913	17	0.53	0.12	1.02	0.12
	Guyana	9	3		24	0.06	0.11		1.00
	Paraguay	69	6		15	1.47	0.03		0.28
	Peru	2663	205	141	112	0.81	0.20	0.28	0.68
	Venezuela	1385	175	675	140	0.78	0.44	0.76	0.51
	Total	24510	12321	9138	9635				

Source: Author's calculations based on DesInventar.

Table 5. Houses Destroyed by Disaster and Country (1970-2010)

Region	Country	Total				By event			
		Floodings	Rainfall&storms	Landslides	Others	Floodings	Rainfall&storms	Landslides	Others
Central America	Costa Rica	1340	21	186	31	0.24	0.10	0.10	0.04
	El Salvador	10582	238	662	359	6.33	0.79	0.79	0.78
	Guatemala	3452	12100	1382	186	3.25	15.82	1.82	2.39
	Honduras	45094	47	996	4235	16.91	0.10	2.00	0.95
	Mexico	168785	142836	10575	1757	25.32	22.26	10.63	0.90
	Panama	4816	526	44	1994	5.65	4.35	0.19	11.68
Caribbean	Dominican Republic	1357	21	25	196	2.95	0.16	1.09	1.69
	Jamaica	63	0	4	0	0.27	0.00	0.07	0.25
	Trinidad and Tobago	28	15	6	0	0.16	1.00	0.22	0.00
South America	Argentina	18914	16134	53	2882	3.18	6.56	1.18	2.60
	Bolivia	2769	297	586	470	1.77	0.78	2.09	1.52
	Chile	3767	26100	60	758	5.22	9.57	0.37	17.27
	Colombia	70532	2126	7037	11499	6.75	1.48	1.42	2.87
	Ecuador	5417	503	1269	168	3.27	0.78	1.42	1.52
	Guyana	35	11		16	0.22	0.41		0.67
	Paraguay	1488	323		635	31.66	1.72		13.87
	Peru	39669	2258	685	232	12.02	2.25	1.36	1.41
	Venezuela	40593	1546	3379	584	22.72	3.87	3.81	2.13
	Total	418701	205102	26949	26002				

Source: Author's calculations based on DesInventar.

4.1 The Disaster Exposure Index (DEI)

Results from the overall DEI, which includes all disasters, are rather unexpected (Table 6). Although the most exposed country is Mexico, an unsurprising result, Argentina, a country usually considered resilient, is in second place with a DEI of 0.74. That Honduras and Guyana are classified as exposed goes in line with other authors' results (Barr, Fankhauser and Hamilton, 2010). More unexpected is the classification of several Caribbean countries as covered when other reports such as IDB (2010), which even uses the same dataset, found the exact opposite result.

As frequent disasters like Flooding are highly weighted in the overall DEI, exposure to other unusual disasters is less apparent than in other measures. Moreover, since previous indexes have focused on different types of disasters, decomposing the DEI by disaster might explain why the results are so different. Figure 2 shows the DEI values for different types of disaster in the six most exposed countries. Mexico ranks as the most exposed in two main disasters, Rainfall and Storms and Landslides, and it is therefore not surprising that the country is ranked as Highly Exposed in the overall DEI. On the other hand, Argentina does not have very high DEIs in

Flooding, Rainfall and Storms or Landslides, but its values are greater than those of Honduras; in addition, Argentina ranks very high in Drought and Fire. Honduras is evenly exposed to all types of disaster, a likely explanation for why it is usually classified as a vulnerable country. Medium exposure countries are affected by specific disasters: Guyana ranks first in Flooding and very high in Droughts; Venezuela and Paraguay, on the other hand, rank high only on Fire.

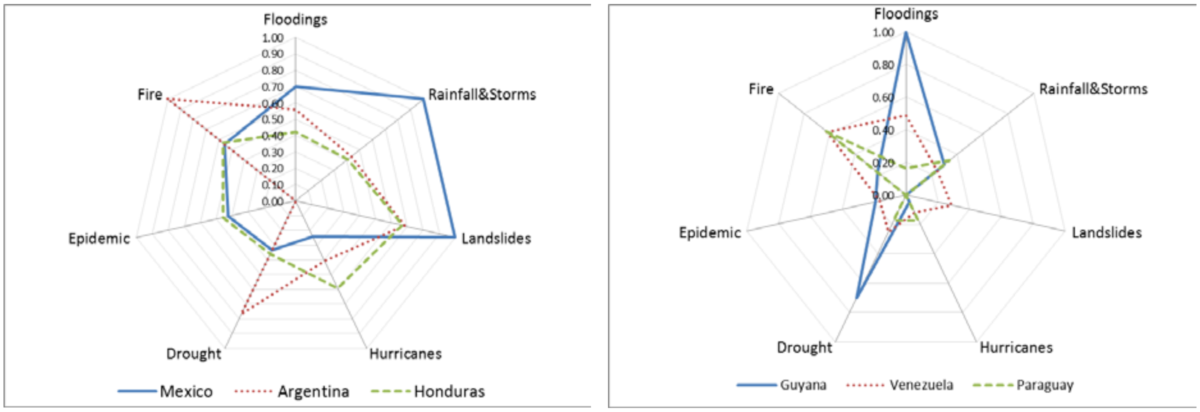
Table 6. Country-Level Disasters Exposure Index (DEI)

Region	Country	Value	Category
Central America	Mexico	1.00	Highly exposed
South America	Argentina	0.74	Exposed
Central America	Honduras	0.72	Exposed
South America	Guyana	0.60	Exposed
South America	Venezuela	0.56	Medium exposure
South America	Paraguay	0.47	Medium exposure
Caribbean	Jamaica	0.46	Medium exposure
South America	Ecuador	0.43	Medium exposure
Caribbean	Trinidad and Tobago	0.35	Not exposed
South America	Bolivia	0.30	Not exposed
Central America	Guatemala	0.28	Not exposed
Caribbean	Dominican Republic	0.24	Not exposed
Central America	El Salvador	0.21	Not exposed
South America	Chile	0.20	Not exposed
South America	Colombia	0.12	Covered
South America	Peru	0.09	Covered
Central America	Costa Rica	0.02	Covered
Central America	Panama	0.00	Covered

Source: Author's calculations based on DesInventar.

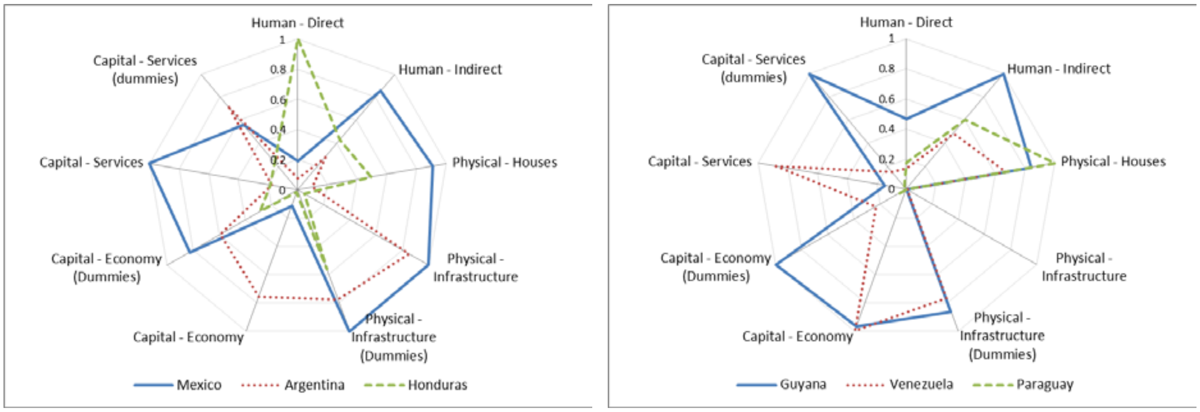
DEI methodology additionally permits observation of patterns in the sub-indexes. As Flooding is the most important event in the region, only the Flooding DEI has been decomposed in Figure 3 (as in Figure 2, only those countries most exposed have been included). Mexico ranks high in almost all sub-indexes, showing severe human and physical impacts. Guyana also suffers high impacts in all types of indicators. Argentina has much lower Human exposure, both Direct and Indirect, but very high exposure in Infrastructure, Economy and Services (only dummies). Honduras has the highest exposure in Direct impact on Humans. The final exposure classification is based on the equal weighting of all types of impact. Robustness analysis[12] suggests that including or excluding certain impacts variables does not affect the final results. If different weights were assigned to certain effects, such as the human indexes, the final picture would probably be different.

Figure 2. DEI Decomposition by Disaster, Six Most Exposed Countries



Source: Author's calculations based on DesInventar.

Figure 3. Flooding DEI Decomposition by Sub-Indexes, Six Most Exposed Countries



Source: Author's calculations based on DesInventar.

An advantage of DesInventar over other data sources is that it registers subnational-level data. The results of the overall DEI at the subnational levels are shown in Map 2. This map shows a predictable scenario in some areas and a surprising one on others. In Mexico there is a clear pattern of High Exposure in the southeast part of the country, especially on the Gulf Coast, an area traditionally hit by tropical hurricanes. In Argentina, provinces at the center of the country suffer floods from rains and river overflows, as shown in Map 1, so medium exposure is

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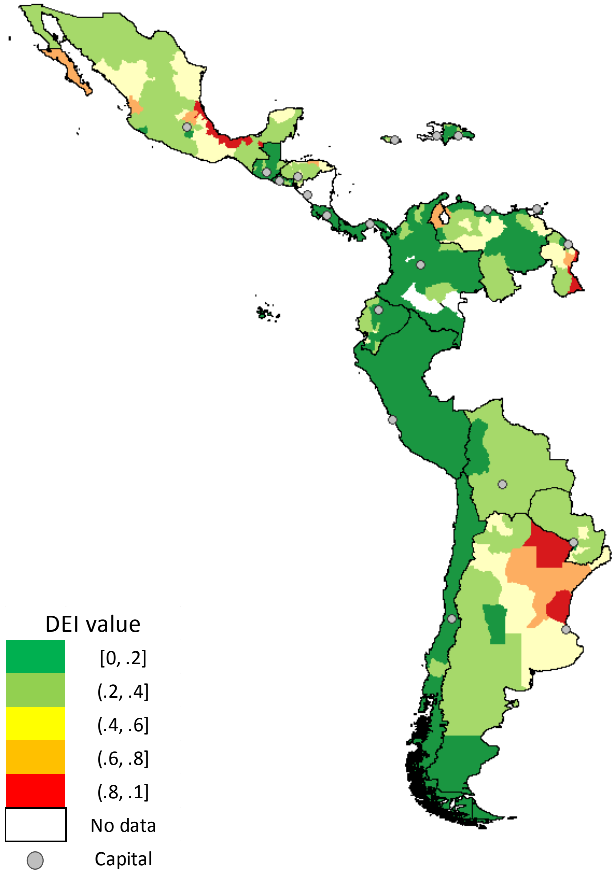
[12] DEI robustness included the comparison of different set of impact indicators to see which ones were more relevant in the final result. Part of this exercise can be found in Tables A8 and A9.

not surprising. Quite unexpected, though, is the high exposure of the northeast region, which is much less densely populated and not usually subject to disasters. The eastern part of Guyana, more populated than the rest of the country, is also more exposed.

Sub-national DEIs, like those at the country level, are highly influenced by the three main disasters: Flooding, Rainfall and Storms and Landslides. The DEIs corresponding to these disasters are shown in Map 3. Areas classified as medium or highly exposed in Flooding-DEI have the same classification (or worse) in overall DEI. Especially clear is the case of Mexico, where all levels of disasters exposure can be seen within the country. Rainfall and Storms mainly affect regions of Mexico, Venezuela and Argentina; in Mexico the regions are mainly located near the Gulf coast and in Argentina in the South. Within countries, areas highly exposed to Landslides are quite specific. Particularly notable are La Paz, Honduras, and Puebla, Mexico, followed by Colon, Honduras, and Zulia, Venezuela.

The overall low exposure at sub-national level can be explained by the categorization according to their DEI values (Table 9). Of the 329 subnational areas, more than 70 percent are categorized as Covered or Not Exposed. Of the remaining areas remaining, 36 are in a situation of Medium exposure, 9 Exposed and only 6 are Highly exposed (Tabasco and Veracruz in Mexico; Formosa, Entre Ríos and Chaco in Argentina; and Mahaica-Berbice in Guyana). This implies that for subnational regions better indicators than DEI should be devised to provide a better picture of smaller geographical areas by providing more exposure categories, adjusting for subnational characteristics and/or changing the calculation methodology. Another approach could involve comparing subnational regions only within countries and not across them, as those regions' socio-economic and geographical differences might render them large non-comparable to areas in other countries.

Map 2. Subnational DEIs



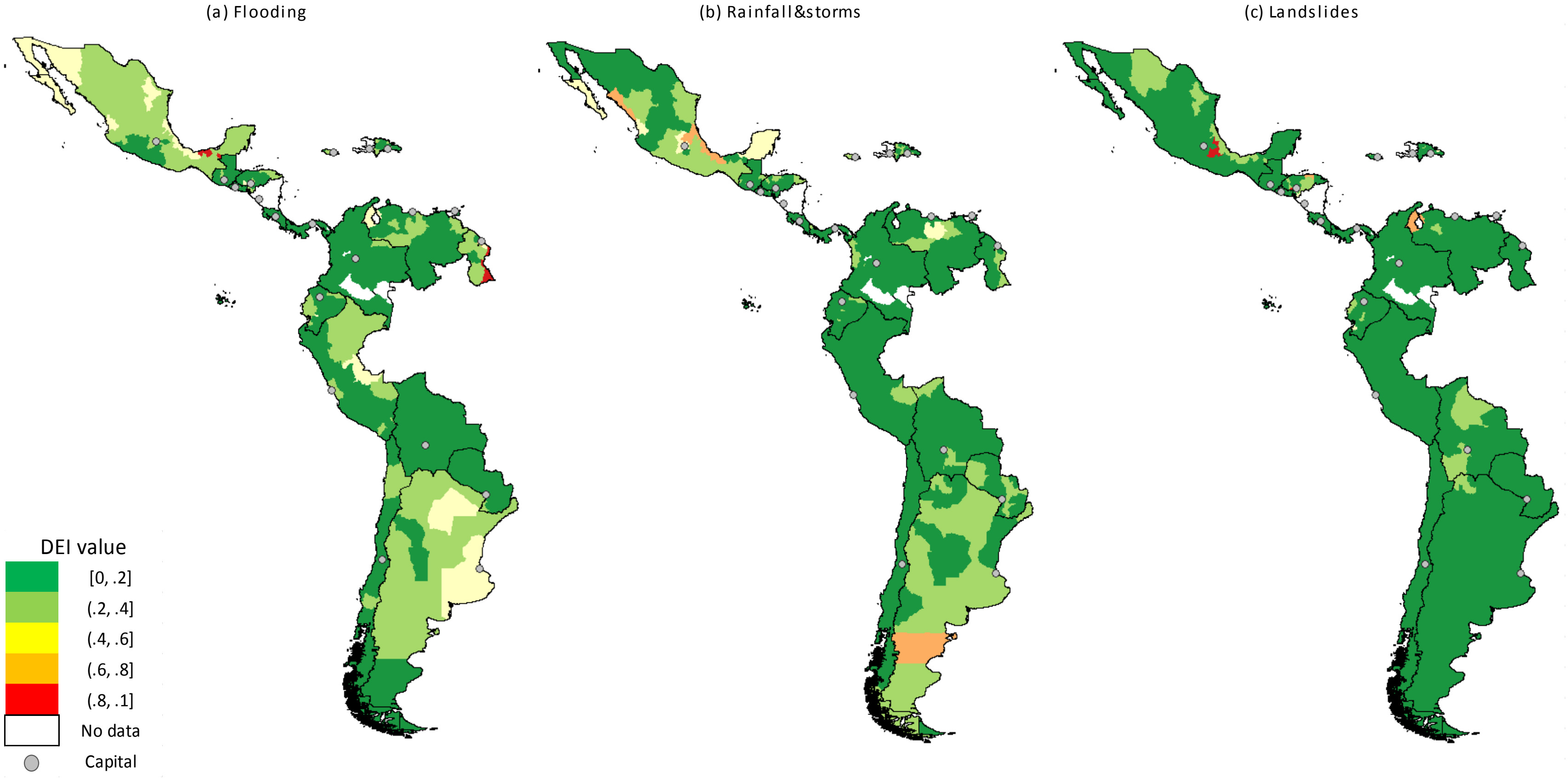
Source: Author's calculations based on DesInventar.

Table 7. Exposure of Subnational Regions by DEI Values

DEI value	Category	Number	Share
[0 ,2]	Covered	163	49.5%
(2, 4]	Not exposed	115	35.0%
(4, 6]	Medium exposure	36	10.9%
(6, 8]	Exposed	9	2.7%
(8, 1]	Highly exposed	6	1.8%
Total		329	

Source: Author's calculations based on DesInventar.

Map 3. Subnational DEIs of Main Natural Disasters


(a) Flooding

(b) Rainfall&storms

(c) Landslides

Source: Author calculations based on DesInventar.

5. Conclusions

The objective of this paper is has been to explore new indicators of exposure to EWEs in Latin America. The results are well founded in previous research on the topic, but they additional provide new insights that could be explored in the future.

The exploration of the general disaster pattern is similar to results from other authors (UN, 2004; Thow and Blois, 2008; Barr, Fankhauser and Hamilton, 2010). Flooding appears as the most prevalent disaster, seen throughout the last 40 years and increasingly important in Central and South America. Mexico is systematically the most exposed country in the region, showing more disasters and human and physical losses than any other country.

In addition, DEI results present a different scenario than those offered by previous estimations. Caribbean countries appear relatively safe, and Central and South American countries look much more exposed. In line with exploratory analysis, Mexico is classified as the most exposed country. Guyana also looks especially exposed, a result previously found only by Barr, Fankhauser and Hamilton (2010). Unexpectedly, Argentina, a country usually classified as resilient, is also greatly exposed.

The subnational-level results are largely unexpected, with the exception of regions in Mexico and Guyana. Other Central American subnational regions appear to be only slightly exposed, and South American regions even less so. Overall, around 50 percent of subnational regions are classified as covered, which seems highly unlikely. Several alternative approaches are available to address this apparent discrepancy. Considering that subnational areas are very different across countries, country-by-country research may be more suitable for detection of sub-national exposure patterns. Complementary approaches could use different levels of geographical disaggregation (e.g., cities and towns), new methods for calculating DEI and correlation of exposure with different variables (geographical area, GDP, existence of rivers, economic activities in the area).

Some of these results could be related with the construction of DesInventar, whose data have rarely been used in the analysis of natural disasters. DesInvestar’s sources, a lack of details on the methodology followed to build the dataset and the variety of agents involved in assembling it are all factors discouraging its use. Nonetheless, DesInventar is one of the most complete datasets available for Latin America countries, including data for many years and featuring a high level of geographical disaggregation. Such a rich source cannot be discarded easily, but efforts should be made to provide data of better quality.

The DEI provides a platform for future development of disaster indicators in the region. Although simple, it is the first time such an index has been developed with DesInventar data. Further refinements are possible in many ways. For example, other authors consider human impact to be the most important indicator of disaster vulnerability (UNDP, 2004; Peduzzi et al., 2009). In addition, the DEI includes impact indicators apart from human impacts and future work could analyze the indicators differently by, for example, weighting human impacts more heavily than at present. Another area for refinement may involve the DEI's criteria for inclusion; the index presently considers events regardless of their intensity, from low to high-impact events. A further alternative is to use other types of disasters to define EWEs. It should finally be noted that, while this paper has only included disasters related with climatic factors, DesInventar provides information on many other types of events that could be object of interest of other investigators, as in IDB (2010).

Climate change is changing how the international community is making assistance decisions, and these decisions have been translated into adaptation funds designed to improve the resilience of developing countries. In turn, assessment of vulnerability and exposure to EWEs are needed so that countries can back up their claims for funds, and DEI provide an additional instrument that can be used in this task. Even so, many concerns exist on how those funds could be diverted for other purposes (Barr, Fankhauser and Hamilton, 2010). Final decisions on funds allocation should be based not only on objective data but also on subjective criteria such as the transparency, efficiency and equity of countries' policies.

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Annexes

A. Additional Tables

Table A1. Countries and Years Available in DesInventar Data

Region	Country	Frequency	Relative frequency	Years		
				Begin	End	Total
Central America	Costa Rica	12750	6.7%	1968	2011	44
	El Salvador	7770	4.1%	1900	2011	112
	Guatemala	4681	2.4%	1988	2010	23
	Honduras	11902	6.2%	1915	2010	96
	Mexico	29067	15.2%	1970	2009	40
	Nicaragua	146	0.1%	1998	1998	1
	Panama	4526	2.4%	1929	2009	81
Caribbean	Dominican Republic	2112	1.1%	1966	2000	35
	Haiti	100	0.1%	2010	2010	1
	Jamaica	844	0.4%	1973	2002	30
	Trinidad and Tobago	594	0.3%	1966	2000	35
South America	Argentina	15466	8.1%	1970	2004	35
	Bolivia	3414	1.8%	1970	2010	41
	Chile	12366	6.5%	1970	2009	40
	Colombia	51890	27.1%	1906	2011	106
	Ecuador	6261	3.3%	1970	2010	41
	Guyana	644	0.3%	1972	2011	40
	Paraguay	384	0.2%	1997	2010	14
	Peru	21086	11.0%	1970	2009	40
	Venezuela	5255	2.7%	1530	2011	482
	Total	191258	100%			

Source: Author's calculations based on DesInventar.

Table A2. Sources of DesInventar

Country	Years with data		Sources
	Begin	End	
Argentina	1970	2004	Officials: Civil defense reports. Newspapers (65%): Clarín; La Nacion; La Prensa; La Razón; Crónica; El Cronista
Bolivia	1970	2010	Newspapers: El Diario
Chile	1970	2011	Newspapers: El Mercurio
Colombia	1900	2012	Officials: Fire Departments; Administrative Department of Prevention, Attention and Recovery System from Disasters (DAPARD); Institute of Research and Geo-Scientific, Mineral, Environmental and Nuclear Information (INGEOMINAS); Red Cross; Local comitees of emergencies and disasters; Departments city halls; OSSO corporation Newspapers: El Tiempo; El Relator; El Pais; El Espectador; El Pais; La Patria de Manizales Other: Maskey(1996), Montero (2001), ERN (2004), CEPAL (1999)
Ecuador	1970	2010	Officials: Fire Department; Red Cross and Police; Technical Secretary of Quito
Guyana	1972	2011	Officials: Fire Service (2003-2011); CDC; ECLAC. Newspapers: Guyana Daily Chronicle (1972-2011).
Paraguay	1997	2010	Officials: National Secretary of Emergencies, Direction of Planification and systematization (2009); Red Cross (2005-2010) Newspapers: Última Hora; ABD digital and others (1997-2008)
Peru	1970	2011	Officials: National Institute of Civil Defense, INDECI (1994-1996) Newspapers: 11 National Newspapers, most from El Comercio.
Venezuela	1700	2012	Officials: National Inventory of Geological Risks, developed by FUNVISIS (1498-2004) Newspapers: El Nacional; El Universal
Costa Rica	1968	2012	Officials: National Commission of Risk Prevention and Emergencies Care, CNE (2005-2010) Newspapers: La Nación (1970 – 2007) Others: Fire Department; Ministry of health.
El Salvador	1900	2011	Officials: National Archive on Health, Goverment and Memories (1900-1914); General archives of the goverment (1901-1914); Fire department (2004-2007); National Comitee of Emergencies (2001) Newspapers: La Prensa Gráfica (1934-2007); El Diario de Hoy (1937-2007); MAS; Del Salvador; Nuevo; Sucesos Migueleños Others: Study on Earthquakes Carlos Caña; Maskrey, Andrew (1993); CEPRODE; Civil Protection; CLESSA, CAES; EEO; SIGET; city halls.
Guatemala	1988	2011	Officials: CONRED; SEGEPLAN. Newspapers: Many, especially Prensa Libre and La Hora
Honduras	1915	2012	Officials: Permanent Comission of Contingencies (COPEC); National Meteorological Service (SMN); Secretary of Natural Resources and Environment (SERNA); National Institute of Statistics (INE); Fire Department of Honduras; National Autonomus University of Honduras Newspapers: La Tribuna and El Heraldo
Nicaragua	1998	1998	N/A
Panama	1929	2012	Officials: National system of civil protection (1996-2008 and others) Newspapers: La Crítica (1986-1996, 2000-2002, 2008-2009 and others)
Mexico	1970	2010	Officials: National System of Civil Protection; Secretary of Health (1992) Newspapers: El Excélsior, El Universal and La Jornada (1970 – 2009)
Haiti	2010	2010	Officials: Direction of Civil Protection (DPC)
Jamaica	1973	2002	N/A
Dominican Republic	1966	2000	N/A
Trinidad and Tobago	1966	2000	N/A

Source: Author's calculations based on DesInventar.

Table A3. Definition of Climate Change-Related Events

Causes		Events	
New name	Original name in dataset	Disaster name	Event name in dataset
Flooding	Lahar	Flooding	Flooding
	High Tide		Alluvium
	Erosion		Surge
	Flooding		Overflow
	Glide		Sedimentation
	Rain And Flooding		Lahar
	Overflow		Liquefaction
Atmospheric conditions	Frost		Tsunami
	Snowfall		Shoreline Change
	Thermal Inversion		Erosion
	Electrical Storm	Rainfall&Storm	Storm
	Fog		Rainfall
	North Wind		Frost
	La Nina		Snowfall
	Storm		Hail
	Rain And Wind		Electrical Storm
	Cold Wave		Cold Wave
	El Nino		Heat Wave
	Atmospheric Conditions		Storm Surge
	Rainfall	Landslide	Glide
Hurricane	Surge		Landslide
	Hail	Hurricane	Gale
	Tornado		Tropical Storm
	Tropical Depression		Hurricane
	Hurricane		Tornado
	Tropical Storm		Storm Surge
	Gale	Drought	Drought
Drought	Heat Wave		Rationing
	Drought	Epidemic	Epidemic
		Fire	Forest Fire
			Fire
			Explosion

Source: Author's calculations based on DesInventar.

B. DEI Construction

The details of DEI construction are explained in this annex.

B.1. Defining Countries and Subnational Regions

For the analysis, it was necessary to disaggregate data at country and subnational levels. Countries were directly available, but subnational areas were harder to define, as they have different characteristics across countries (names, political attributions and geographic size); moreover, in some cases boundaries have recently changed. First administrative divisions were used as subnational regions: provinces for Argentina, Costa Rica, the Dominican Republic and Ecuador; departments for El Salvador, Guatemala, Honduras, Bolivia, Colombia and Paraguay; states for Mexico and Venezuela; regions for Chile, Guyana and Peru; provinces and counties for Panama; parishes for Jamaica; and regions and municipalities for Trinidad and Tobago.

Another reason for the lack of homogeneity was the use of maps' coordinates. To construct maps, coordinates were obtained from http://www.gadm.org/. Some outdated boundaries were found, as in the case of Chile: GADM includes the coordinates of 13 regions, but since 2006 Chile has been into 15 regions. To obtain harmonization between maps and sub-national calculations, the analysis was undertaken disaggregating data according to GADM administrative divisions. For this reason the total number of subnational entities does not coincide with recent administrative divisions.

B.2. Selecting and Managing Indicators

Impact variables on human and physical areas are widely available in DesInventar, so the same impacts indicators were used for all countries. The only variables discarded were those related with monetary losses because there is no guarantee that these are precise, as the main data sources of DesInventar are newspapers.

Units of measurement and types of impact variables were different. Some variables were measured in number of persons affected or missing, while others were measured in number of houses destroyed. On the other hand, while some variables contained real numbers, others were dummy variables equal to one if the sector was affected. For example, while the variable "routes" contained the number of kilometers affected by the disasters, the variable transport was equal to 1 if transportation was affected by the disaster. To observe the contribution of each type of impact and each type of variable to the overall DEI index, several sub-indexes were estimated. The description of these measures and impact variables can be observed in Table B1.

Table B1. Impact Variables Used in the DEI

Type of impact	Sub-index name	Variable	Type	Unit of measurement
Human - direct	D1.1	Deaths	Number	Persons
		Missing	Number	Persons
		Wounded and sick	Number	Persons
Human - indirect	D1.2	Victims	Number	Persons
		Affected	Number	Persons
		Evacuees	Number	Persons
		Relocated	Number	Persons
Physical - houses	D2.1	Destroyed	Number	Houses
		Affected	Number	Houses
Physical - capital - infraestructure	D2.2.1ND	Routes	Number	Kilometers
	D2.2.1D	Transport	Dummy	=1 if transport was affected
		Communications	Dummy	=1 if communications were affected
		Aqueduct	Dummy	=1 if aqueducts were affected
		Sewerage	Dummy	=1 if sewerages were affected
Physical - capital - economy	D2.2.2ND	Crops and wood	Number	Hectares
		Livestock	Number	Animals
	D2.2.2D	Agriculture and livestock	Dummy	=1 if agriculture and livestock was affected
		Energy	Dummy	=1 if energy was affected
		Industry	Dummy	=1 if industry was affected
Physical - capital - services	D2.2.3ND	Education	Number	Education centers
		Health centers	Number	Health centers
	D2.2.3D	Education	Dummy	=1 if education center was affected
		Aid organization	Dummy	=1 if aid organization was affected
		Health	Dummy	=1 if health organization was affected

Source: Author's calculations based on DesInventar.

B.3. Normalizing Indicators and Obtaining Sub-Indexes

The methodology used to construct the DEI is based on the one used to calculate the HDI in UNDP (2006). In this method, a first step in constructing the index is to normalize indicators values. Since indicators vary in units and scales, in order to obtain figures which are free from the units and also to standardize their values they are normalized so that they all lie between 0 and 1. Before doing this, it is important to identify the functional relationship between the indicators and exposure. Two types of functional relationships are possible: exposure increases with increase (decrease) in the value of the indicator. If a higher value of the indicator is associated with greater exposure is greater then there is a positive relationship with the indicator. The formula to normalize its values is:

$$x_{ij} = \frac{X_{ij} - Min\{X_{ij}\}}{Max\{X_{ij}\} - Min\{X_{ij}\}} \qquad (1)$$

where X_{ij} are the original values of the indicator and x_{ij} are the normalized ones. For x_{ij} the value 1 will correspond to that region with the maximum value and 0 will correspond to the region with the minimum. In my case all indicators have a positive relation with exposure, so equation (1) was used to normalize all of them.

After normalizing indicators they were averaged to obtain each one of the sub-indexes. Then the average of these sub-indexes was calculated. By construction, this final result does not necessarily lie between 0 and 1. To simplify the DEI measure these last values were standardized by formula (1).

A simple example of these steps can be seen in Table B2, which presents the numbers only for Flooding. In this table the total number of Deaths, Missing and Wounded & Sick are shown. For each one of these exposure indicators, their values are normalized between 0 and 1. After the normalization it is easier to see that Honduras is highly exposed in terms of deaths or missing but Mexico is much more exposed in terms of Wounded & Sick. The average of these normalized values results in a series of values that do not lie between 0 and 1, so they are normalized using formula (1), and the result is defined as the sub-index D1. Finally, the exposure categories can be found in the last column.

Table B2. Construction of D1.1-Simple for Flooding

Region	Country	Total			Normalized			Average	Normalized average	Category
		Deaths	Missing	Wounded&Sick	Deaths	Missing	Wounded&Sick			
Central America	Costa Rica	129	32	6	0.01	0.00	0.00	0.01	0.0065	Covered
	El Salvador	717	87	46	0.07	0.01	0.00	0.03	0.0355	Covered
	Guatemala	177	89	887	0.02	0.01	0.07	0.03	0.0415	Covered
	Honduras	10202	9279	3780	1.00	1.00	0.30	0.77	1.0000	Highly exposed
	Mexico	3611	3427	7578	0.35	0.37	0.60	0.44	0.5748	Medium exposure
	Panama	77	35	448	0.01	0.00	0.04	0.02	0.0196	Covered
Caribbean	Dominican Republic	202	73	23	0.02	0.01	0.00	0.01	0.0121	Covered
	Jamaica	90	16	8	0.01	0.00	0.00	0.00	0.0041	Covered
	Trinidad and Tobago	17	0	0	0.00	0.00	0.00	0.00	0.0000	Resilient
South America	Argentina	755	326	6728	0.07	0.04	0.53	0.21	0.2782	Not exposed
	Bolivia	552	107	472	0.05	0.01	0.04	0.03	0.0441	Covered
	Chile	242	138	785	0.02	0.01	0.06	0.03	0.0431	Covered
	Colombia	2731	1297	3090	0.27	0.14	0.24	0.22	0.2830	Not exposed
	Ecuador	882	142	306	0.09	0.02	0.02	0.04	0.0541	Covered
	Guyana	9	0	1478	0.00	0.00	0.12	0.04	0.0505	Covered
	Paraguay	69	0	0	0.01	0.00	0.00	0.00	0.0022	Covered
	Peru	2663	1324	12650	0.26	0.14	1.00	0.47	0.6102	Exposed
	Venezuela	1385	626	23	0.13	0.07	0.00	0.07	0.0886	Covered

Source: Author's calculations based on DesInventar.

B.4 Aggregation across Disasters

The previous procedure was performed by disaster for each country and subnational region. In order to provide a single number, however, DEI across disasters had to be aggregated. This could not be done by simply averaging the DEI for all disasters, as that would imply that each disaster is equally likely to occur. In order to consider this point the frequency of each disaster was divided by total frequencies for each country, and this calculus was used as weight in the aggregation. For example, supposing an estimated DEI for flooding and droughts of 0.5 and 0.7, respectively, the average would be 0.6 (0.5+0.7 / 2). Now suppose that of 150 events 125 are Flooding and 25 are Droughts. Then the "probability" that a flooding will occur is 0.83 (125/150) and a Drought is 0.17 (25/150). Then the weighted EVI is 0.52 (0.83*0.5 + 0.17*0.7). Disaster probabilities estimated at country level used can be found in Table B3.

Table B3. Probabilities of Disasters Analyzed

Region	Country	Flooding	Rainfall&storm	Landslide	Hurricane	Drought	Epidemic	Fire
Central America	Costa Rica	66.2%	2.4%	23.0%	4.9%	3.5%	0.0%	0.0%
	El Salvador	51.1%	9.2%	25.5%	6.9%	4.2%	0.3%	2.9%
	Guatemala	39.7%	28.6%	28.4%	1.3%	0.2%	0.1%	1.7%
	Honduras	32.8%	6.0%	6.1%	10.8%	7.5%	35.5%	1.2%
	Mexico	40.0%	38.5%	6.0%	6.0%	5.7%	1.2%	2.6%
	Panama	62.1%	8.8%	16.6%	10.9%	1.0%	0.0%	0.5%
Caribbean	Dominican Republic	62.9%	18.1%	3.1%	15.6%	0.0%	0.3%	0.0%
	Jamaica	56.6%	12.4%	14.1%	7.2%	2.1%	2.9%	4.8%
	Trinidad and Tobago	77.6%	6.6%	11.8%	1.8%	0.0%	1.3%	0.9%
South America	Argentina	62.2%	25.7%	0.5%	5.1%	4.9%	0.0%	1.7%
	Bolivia	61.7%	15.1%	11.1%	2.0%	9.3%	0.2%	0.6%
	Chile	19.7%	74.6%	4.4%	0.6%	0.2%	0.0%	0.3%
	Colombia	50.0%	6.9%	23.7%	14.4%	2.0%	0.0%	3.0%
	Ecuador	49.6%	19.3%	26.8%	2.1%	0.8%	0.8%	0.6%
	Guyana	75.7%	12.9%	0.0%	5.2%	5.2%	0.5%	0.5%
	Paraguay	16.3%	65.3%	0.0%	3.1%	14.2%	0.0%	1.0%
	Peru	66.4%	20.2%	10.1%	0.6%	0.8%	1.9%	0.1%
	Venezuela	53.4%	11.9%	26.5%	5.4%	0.4%	0.3%	2.2%

Source: Author's calculations based on DesInventar.

B.5 Comparison of DEI Versions

Different versions of the DEI were estimated to evaluate which one provided the most appropriate exposure to disasters scenario in Latin America. These versions varied in the type of impact variables considered and the adjustment of them from different points of view. Table B4 provide a brief exposition of this exercise.

Table B4. All Disasters Exposure Index (DEI)

Region	Country	Simple		Population adjusted		Per event adjusted	
		Without dummies	With dummies	Without dummies	With dummies	Without dummies	With dummies
Central America	Costa Rica	0.0272	0.1135	0.3034	0.8589	0.0000	0.0000
	El Salvador	0.0264	0.1032	0.1640	0.2715	0.0644	0.1891
	Guatemala	0.0851	0.0750	0.3442	0.2084	0.3448	0.2653
	Honduras	0.6266	0.5128	1.0000	1.0000	0.5847	0.4400
	Mexico	1.0000	1.0000	0.7054	0.7577	0.9979	0.9290
	Panama	0.0049	0.0084	0.0993	0.0835	0.0495	0.0052
Caribbean	Dominican Republic	0.0158	0.0402	0.0000	0.0014	0.0774	0.3784
	Jamaica	0.0193	0.0369	0.0491	0.0157	0.1026	0.5191
	Trinidad and Tobago	0.0220	0.0180	0.0408	0.0071	0.0633	0.4494
South America	Argentina	0.7030	0.6721	0.6285	0.8256	0.5248	0.6402
	Bolivia	0.0555	0.0726	0.1131	0.0913	0.1105	0.2078
	Chile	0.1612	0.1321	0.8928	0.6505	0.5054	0.3923
	Colombia	0.4102	0.5799	0.4027	0.6936	0.1629	0.1358
	Ecuador	0.1251	0.2300	0.4615	0.3332	0.2739	0.4051
	Guyana	0.0453	0.0297	0.9052	0.4232	1.0000	1.0000
	Paraguay	0.0000	0.0000	0.0158	0.0000	0.1697	0.3354
	Peru	0.2214	0.1809	0.1439	0.2729	0.2463	0.2377
	Venezuela	0.2943	0.1946	0.5115	0.2641	0.6925	0.3875

Source: Author’s calculations based on DesInventar.

Two major categories of DEIs are those that include dummy impact variables and those that do not. Dummies are not strictly comparable with number impact variables, as they can only take the value 1 without consideration of the size of the impact. Including dummies might therefore bias the analysis of disasters exposure. This is why, for each DEI type, two additional categories were estimated: one including all dummies and another including none (appearing as with and without in Tables A5 and A6).

The versions varied in their consideration of exposure. The simple DEI version was calculated using indicators “as is,” that is, no adjustment was made to control for countries’ or regions’ characteristics. An important variable to consider in this version is population. The more populated a country is, the more likely it is that a natural disaster will not only affect people but also a larger number of people. For this reason the second series of DEI was calculated dividing all indicators by the country’s population in that year. Other important variables are GDP and GDP per capita. Lack of resources to prevent or adapt to extreme events makes poorer countries more likely to suffer a disasters, and impact variables were adjusted by GDP and GDP per capita to adjust for this fact. The last series of DEI used the impact per event as indicator. For example, if the total number of deaths was 1,000 in 50 floods then 20 deaths per event was used instead of 1,000 (the latter number was the type used in the simple version of the DEI).

Table B5 presents the correlation of DEI values at country level. It is easily seen that the differences between DEI versions are negligible. Correlations are relatively high, above 0.5 in most cases, and positive. For the same type of DEI, the correlation of DEI versions without and with dummies is extremely high, making the case for including dummies to use all data available. Correlations across correlations were also very high, being relatively lower only in GDP adjusted compared with the others, and the per event adjusted DEI version is highly correlated with all adjusted versions. Since GDP adjustment could mix exposure with resilience (an issue aspect that I am not interested), per event adjusted GDP was selected for the analysis.

Table B5. National-Level DEI Correlations

Type of adjustment	**Dummies indicators**	**Simple**		**Population adjusted**		**GDP adjusted**		**GDP per capita adjusted**		**Per event adjusted**	
		Without	**With**	**Without**	**With**	**Without**	**With**	**Without**	**With**	**Without**	**With**
Simple	Without	1									
	With	0.98	1.00								
Population adjusted	Without	0.80	0.75	1.00							
	With	0.75	0.77	0.86	1.00						
GDP adjusted	Without	0.56	0.50	0.69	0.50	1.00					
	With	0.47	0.46	0.58	0.49	0.93	1.00				
GDP per capita adjusted	Without	0.71	0.66	0.74	0.55	0.93	0.83	1.00			
	With	0.73	0.70	0.72	0.60	0.91	0.90	0.95	1.00		
Per event adjusted	Without	0.82	0.74	0.85	0.57	0.60	0.42	0.74	0.66	1.00	
	With	0.76	0.71	0.66	0.42	0.49	0.39	0.64	0.62	0.87	1

Source: Author's calculations based on DesInventar.

The subnational-level scenario is shown in Table B6. At this geographical level only simple and per event versions could be calculated. Correlations are not as high as in the country-level scenario, especially between simple and per event versions. As in the country-level, one likely reason is that subnational areas' characteristics (population, GDP, geographical area) are correlated with frequencies. Adjustment per event would control for this fact.

Table B6. Subnational-Level DEI Correlations

Type of adjustment	Dummies indicators	Simple		Per event	
		Without	With	Without	With
Simple	Without	1			
	With	0.94	1.00		
Per event adjusted	Without	0.65	0.50	1.00	
	With	0.51	0.47	0.73	1

Source: Author's calculations based on DesInventar.