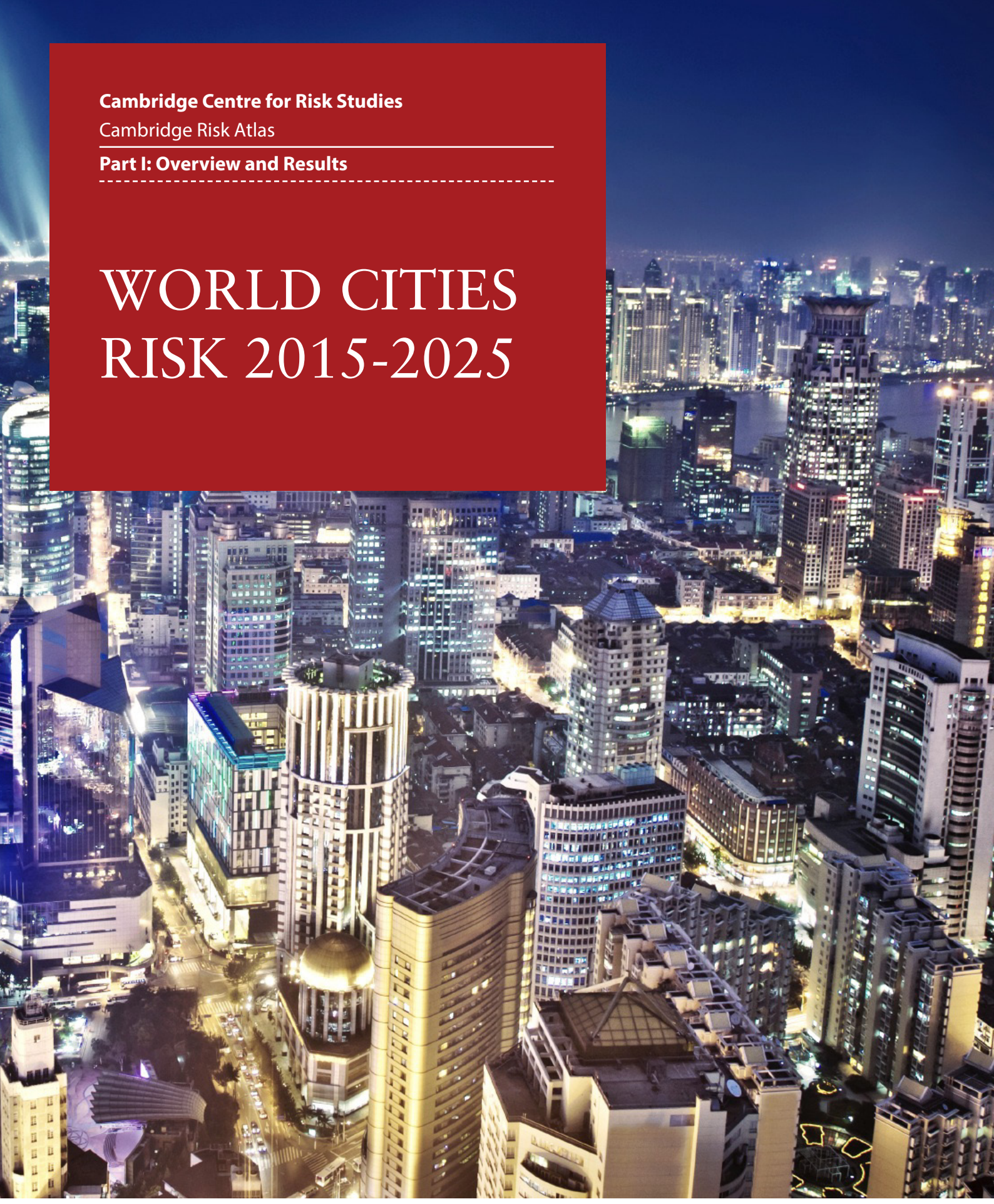
Cambridge Centre for Risk Studies

Cambridge Risk Atlas

Part I: Overview and Results

WORLD CITIES RISK 2015-2025



Centre for
Risk Studies

UNIVERSITY OF CAMBRIDGE
Judge Business School

Cambridge Centre for Risk Studies
University of Cambridge Judge Business School
Trumpington Street
Cambridge, CB2 1AG
United Kingdom
enquiries.risk@jbs.cam.ac.uk
http://www.risk.jbs.cam.ac.uk/

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Part I: Overview and Results

World Cities Risk 2015-2025

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World City Risk 2015

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1 Executive Summary

A comprehensive approach to the assessment of catastrophe damage on World Cities

This World City Risk report presents the first analysis that assesses the combined damage inflicted on global cities by a comprehensive set of significant and recurrent threats. We consider some 23 threats in five broad threat classes: Natural Catastrophe & Climate, including threats such as earthquake and windstorms; Financial, Trade & Business including threats such as market crashes, and commodity price shocks; Politics, Crime & Security, including political instability, conflicts and terrorism; Technology & Space, e.g. cyber catastrophe; and Health & Environment, e.g. pandemics and famines.

300 World Cities

Our key output is a ranking of 300 World Cities by their propensity to experience harm. These cities are selected for their economic and geographical significance; they account for around 50% of global GDP today and an estimated two-thirds of global GDP by 2025. This report proposes a unifying metric of loss, GDP@Risk, that measures the average loss anticipated over a decade from threats across the five threat classes.

Are Taipei and Tokyo the world's riskiest cities?

Taipei and Tokyo form the top tier of cities with respect to GPD@Risk, with tier 2 comprising of Istanbul, Manila, Seoul and Tehran. The tier 3 cities are Bombay, Buenos Aries, Delhi, Hong Kong, Lima, Los Angeles, New York and Osaka. The remaining 35 of the 50 riskiest World Cities are split into: tier 4, some 25 cities topped by Sao Paolo and including Beijing, Chicago, Jakarta, Karachi, London, Mexico City, Moscow, Paris and Riyadh; and tier 5: 10 final cities including Cairo, Calcutta, Kiev, Lagos and Santiago.

Taipei, Tokyo, Istanbul, Osaka exemplify high economic value cities with high exposure to natural catastrophes, interstate war and also market crashes and oil price shocks. A similar description applies to Los Angeles and New York, but with cyber threats instead of war; and also to Hong Kong and Shanghai where risk is augmented significantly by the threat of human pandemic. War, separatism and terrorism pose a third or more of the risk faced by the cities of Bombay, Buenos Aries, Seoul and Tehran.

Framing each threat

This report is based on the historical record and attendant scientific models of 23 different threats or perils. The past occurrence of catastrophic events is used as a guide to future incidents. Each threat is framed via three characteristic scenarios which vary in magnitude from moderate to very severe. The geography of risk from different threats is illustrated in our Risk Atlas, which provides a world map corresponding to each threat, indicating the proximity of cities to threats, or the contours of magnitudes posed by each threat.

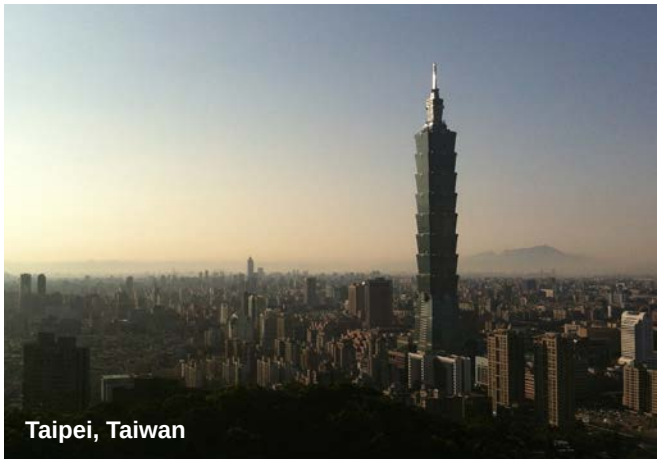
Characterising cities

Cities, due to their different locations, may have a different likelihood of being exposed to any of the three characteristic scenarios for a given threat type. Each city can also be characterized by its economic mix, population over time, quality of construction or the vulnerability of its physical assets, and an index of economic resilience, constructed from several factors such as social cohesion, governance capability, value of capital infrastructure, etc. These city characteristics determine the impact, namely value of economic loss, of any of the characteristic scenarios. The average loss combines the chance of exposure to a threat scenario over one decade, with the level of economic damage inflicted by that scenario. GDP@Risk is the sum total of losses experienced by all 300 World Cities over all threats and characteristic threat scenarios.

Loss makers topped by Financial Crisis, Human Pandemic and Natural Catastrophes

The top six threats with respect to their total GDP damage across the 300 World Cities are Financial Crisis, Interstate War and Human Pandemic, closely followed by the Natural Catastrophe triad of Windstorm, Earthquake and Flood. About a fifth of GDP@Risk is due to Financial Crisis alone, while these six perils together generate more than 60% of GDP@Risk. Cyber, Separatism, Oil Price Shock and Sovereign Default round out the top 10 threats which, combined, are to blame for around 90% of GDP@Risk.

For comparison, we have compiled the cumulative direct losses inflicted by several thousand catastrophe events since 1900. The results demonstrate that


Taipei, Taiwan


Tokyo, Japan

our model produces relativities of risk of economic output loss between threats that are consistent with the direct losses between threats in the past. With respect to Natural Catastrophes in particular, our study concurs with Swiss Re's city vulnerability analysis from 2013.

Future risk for World Cities

Our analysis identifies three important trends in the global risk landscape that we refer to as 'future risk'. The first is that emerging economies will shoulder an increasing proportion of GDP@Risk as a result of accelerating economic growth, which itself results from population growth. The second trend is the growing prominence of man-made threats. Finally, we see a heavy contribution, representing more than a third of GDP@Risk, of threat types which are rapidly developing, like Cyber events, and therefore can be viewed as emerging risks.

Catastrophes losses place a burden of 1.5% on global GDP

The analysis suggests that the expected loss across all threat classes amounts to $5.4 trillion for the 300 World Cities from 2015 to 2025. The baseline is the forecast total GDP output of these cities over the same period: some $370 trillion. The expected loss from catastrophes, therefore, is 1.5% of total GDP output. Economists project that the world's economy will average 3.2% growth for the next decade. Our estimation of expected catastrophe loss amounts to about half of the expected global growth rate. This analysis suggests that catastrophes put a burden of 1.5% on the world's economic output. If catastrophe losses were made obsolete, economic growth would be significantly higher.

Mitigation gains could be substantial

Mitigation of catastrophe losses is an investment that could potentially yield an enormous benefit in perpetuity if, by investing in more resilient institutions and stronger infrastructure, the burden of disaster on economic growth were reduced. This is discussed further below.

The process for GDP@Risk is not statistical; it is estimated without providing a confidence interval around the figure of $5.4 trillion. We can test this value by asking how sensitive it is to changes in the characteristic scenarios which describe each threat. Taking climate change as a possible driver of uncertainty in our analysis, we consider the possibility that the frequency of Wind Storm, Flood, Drought, Freeze and Heatwave is 10% greater than in our base models, and the corresponding event severities are 5% higher. The effect is to increase GDP@Risk by 5%.

The modelling process also allows us to ask what value might be gained globally by a hypothetical improvement in physical vulnerability or economic resilience of all World Cities. Indeed, about half of GDP@Risk can be recovered, in principle, by improving these aspects of all cities.

Irrespective of the precise values of GDP@Risk, the ranking of cities by GDP@Risk is quite stable. It is relatively little affected by sensitivity tests of the various threats.

Conclusion

Our analysis of a comprehensive set of threats applied to the 300 World Cities is a first in global risk analysis. The economic metric of GDP@Risk provides comparability of cities across all threats and delivers a risk ranking that shows the importance of systemic events, like Human Pandemics, and man-made catastrophes, such as Financial Crises, beyond the traditional purview of natural disasters. It is also suggestive of where investment can make a large impact in risk reduction. Recognizing risk, mapping it out and measuring it consistently are the keys to managing it in both the long and the short term. This study is a significant step in that direction.

2 Overview

This project provides an analysis of the impact of crises on economic output from the world's 300 most major cities. It is the first known quantitative study of a comprehensive range of threats on cities and how much impact they may have. It provides a common benchmark of risk to allow different cities to be ranked and for the influence of each threat to be compared.

Previous studies have tended to analyze individual threats or to focus on natural hazards, such as earthquake, wind storm, and flood.[1] Natural hazards are destructive and spectacular shocks that pose a significant threat to certain parts of the globe, but they are not the only threats to the ongoing welfare of the world's cities. Our analysis suggests that natural hazards account for less than a third of the causes of economic disruption that could be expected in the world's leading cities. A comprehensive review of all the threats which could potentially cause damage and disruption to social and economic systems has identified five primary classes of threats, and around 55 individual threat types.[2] This taxonomy of threats demonstrates that we live in a world where crises can, and do, occur from a wide range of potential causes, many of them unexpected. Good and informed preparation for the wide range of different types of potential crisis is a key requisite for effective risk management. This report provides a guide to the risk of economic disruption to the world economy from all the major causes of global threat.

Some catastrophes undoubtedly generate growth in the process of recovery and can be net positives for some societies and in certain situations. These recoveries attract capital from elsewhere and use it more efficiently than it might have been otherwise, to boost economic output beyond the level that it would have achieved if the catastrophe had not occurred. In general however, most catastrophes leave a city or region, and the global economy, worse off than if they had not occurred.

In this study we have taken a wide range of threats and standardized an approach to assessing the impact that each would have on a particular city, and produced a common process for assessing the likelihood of these shocks occurring.

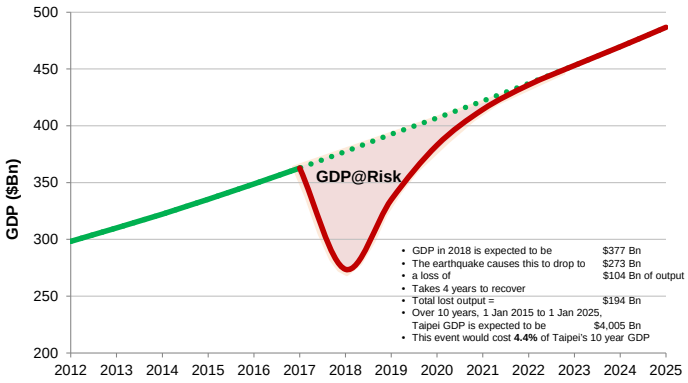


Figure 1: Illustration of methodology employed in this study. A characteristic scenario of an earthquake (Scenario EQ2) impacts Taipei in 2017, taking several years to recover. The lost GDP, relative to its projection is measured as GDP@Risk

This provides a risk metric – *GDP@Risk* – which is the probability-weighted loss (expected loss) of economic output that could be expected from these crises over the next ten years. GDP@Risk is a metric that can be used across very different types of threats as a method of comparison, and in a way that avoids other metrics of loss, such as number of deaths or repair costs of damaged property, which skew the results towards the most deadly or physically destructive threats. Here, we are concerned with all threats that can disrupt our economic well-being.

This is the metric that affects how global businesses view the world. The disruption to markets and production that these catastrophes cause reflects the revenue losses, supply chain interruptions, and operational risks that an international corporation will face in doing business in these locations over the next decade.

The risk analysis of this wide range of threats is not a prediction, and does not expect that these specific losses will occur. We are considering extreme events with low likelihoods, long "return periods" and a high degree of unpredictability and uncertainty as to where and when they will occur. These proposed crises are all extremely unlikely to take place in this ten year timeframe for any one of the cities on our list. But some of the cities will be unlucky and crises will affect them.

Crises of these types continue to materialize throughout the world and the rate at which they have occurred in the past is a guide to how often they might occur in the future. The effects such crises will have today and which locations they hit hardest, however, could be vary greatly from events in the past.

[1] For example Swiss Re, 2013, Mind the Risk: A global ranking of cities under threat from natural disasters.

[2] Cambridge Centre for Risk Studies, 2014, *A Taxonomy of Threats for Complex Risk Management.*

Port au Prince, Haiti, after the 2010 earthquake (Credit: Marco Dormino, UN)

Catastrophes like those used in this analysis are rare and surprising when they occur. The unpredictability of crises and the long intervals between them means that societies are often unprepared for their appearance and consequences. If a particular disaster has not befallen a city in living memory, it is natural for the occupants of that city to fail to anticipate it happening in the future. Human nature tends to discount rare occurrences from our risk perception. However, painstaking scientific studies of the time and place these crises occur have built up a picture of the geography of these threats and the frequency and severity of their appearance. This study pulls together the authoritative published science on a wide variety of threats.

The science of each threat shows where in the world it is likely to occur, how often and with what severity. This analysis has compiled the leading scientific studies on each threat and applied them to assess these risks for the main cities of the world. The location and circumstances of each city influences the likelihood of its experiencing each particular threat. The proximity of the city to the coast and its location within a hurricane belt determines how likely it is to be damaged by a coastal storm surge flood. We can tell how likely the city is to experience a severe freeze event that will halt the city's transport system from its climatic zone and past temperature records. Financial systems, regulations and credit risk ratings determine the possibility of bank runs and sovereign defaults.

The geopolitical risks that a city faces are the result of government policies, social and demographic pressures, and historical enmities that are documented and are studied in detail by political scientists.

This study has collated these individual areas of expertise into a standardized structure of analysis. Twenty-three individual threats have been studied and the available science on each one has been assembled into a threat model. Each threat model includes a definition of three characteristic scenarios of different severities (a moderately severe, severe, and very severe scenario) which illustrate the range of potential catastrophic impacts that a specific threat could wreak on a city. Then, for each city, we estimate the annual probability of a characteristic scenario based on how often events have occurred in the past, hazard maps produced by the subject matter specialists, and other threat assessment studies. The analysis then considers, if that scenario occurred, how the city would be affected and how much the city's economic output would be reduced by that scenario's occurrence. The risk of that loss is the probability multiplied by the loss – the risk of a one in 1000 annual probability of a scenario that generates a billion dollar loss is, therefore, an "expected loss" of one million dollars. We express all these expected loss values as GDP@Risk.

These risks are calculated for each characteristic scenario, for each threat, and for each city. The expected GDP loss values are calculated for the ten year period of 1 January 2015 to 1 January 2025. These are compared with the total GDP that is projected for that city for the same ten year period. GDP@Risk is expressed as total value of loss, usually in billions of $US, and also as a percentage of the total projected GDP for that city over the next ten years.

The impact of these risks is then summed up in various ways. The total GDP@Risk from all the threats to each city is used to rank the cities by their chance of suffering economic disruption from any type of crisis – we can assess which threats pose the greatest risk to each city. For any threat, we can review which cities are most at risk. Across all of the 300 cities used to represent the main cities of the world, we can assess which threats pose the greatest risk of loss of GDP to the world economy. This standardized metric is a very useful way of comparing and contrasting different components of the risk.

Part II of this report describes the methodology of how this risk assessment was made.

The next section summarizes the results and the conclusions that can be drawn from the analysis.

3 Risk Atlas

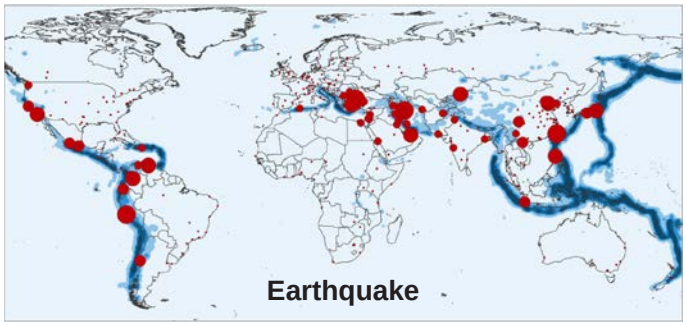
The appendix to this report is a Risk Atlas of all of the individual threat maps and the results of the GDP@Risk analysis for each threat, with the symbol size for each city representing the total GDP@Risk from that threat.

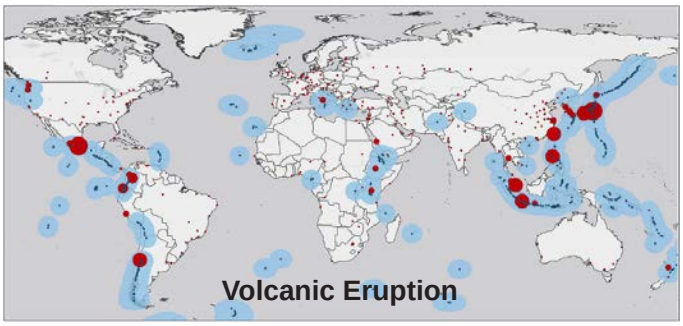
Note that the scales for the value of GDP@Risk on each of the maps are different, as each map uses its own appropriate scale to highlight the relativities between cities for that threat.

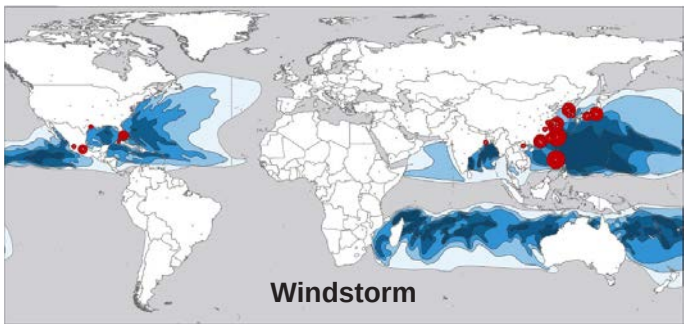
The maps are presented as world maps, and each shows the geography of risk from that threat, with the expected loss to each city over the next decade, as GDP@Risk.

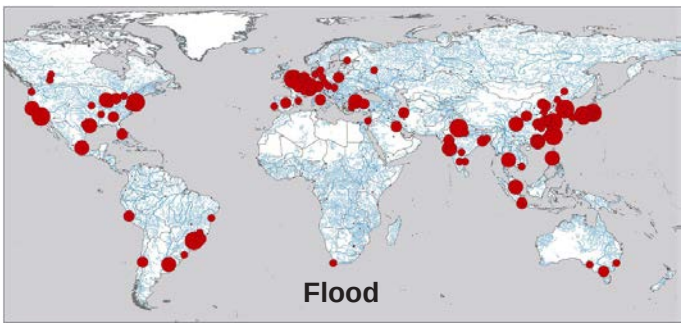
The top 10 cities most at risk from each threat are identified. These are the cities that have the largest GDP@Risk because of their geographical location, their exposure to the hazard of the threat severity for that city, the physical vulnerability of the city, and their resilience and ability to recover from a crisis.

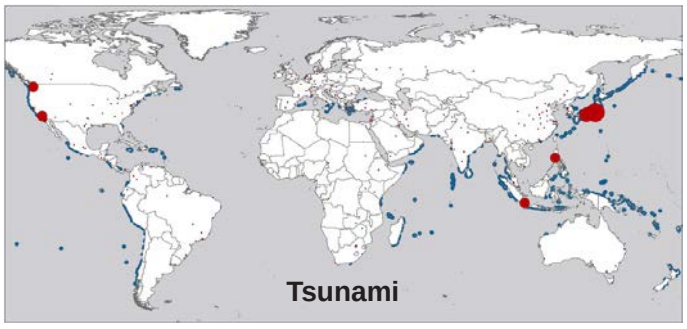
In general, cities that have the largest GDPs have higher values of GDP@Risk – even moderate threats can cause large values of loss. However, although some cities with large GDP do feature commonly in the top ranks of the risks across several threats, the patterns of threat identify a wide range of different cities in different threat types.

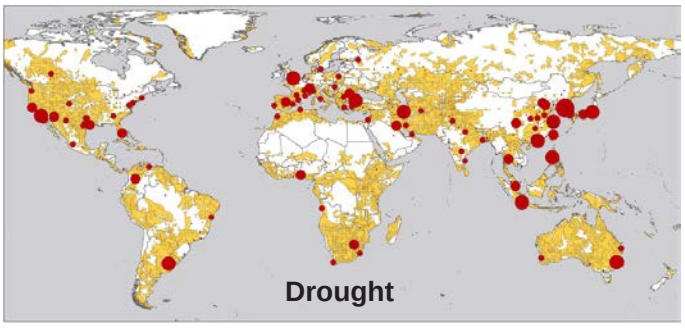












Examples from the Cambridge World City Risk Atlas: Threat Hazard Maps of the World

4 Results

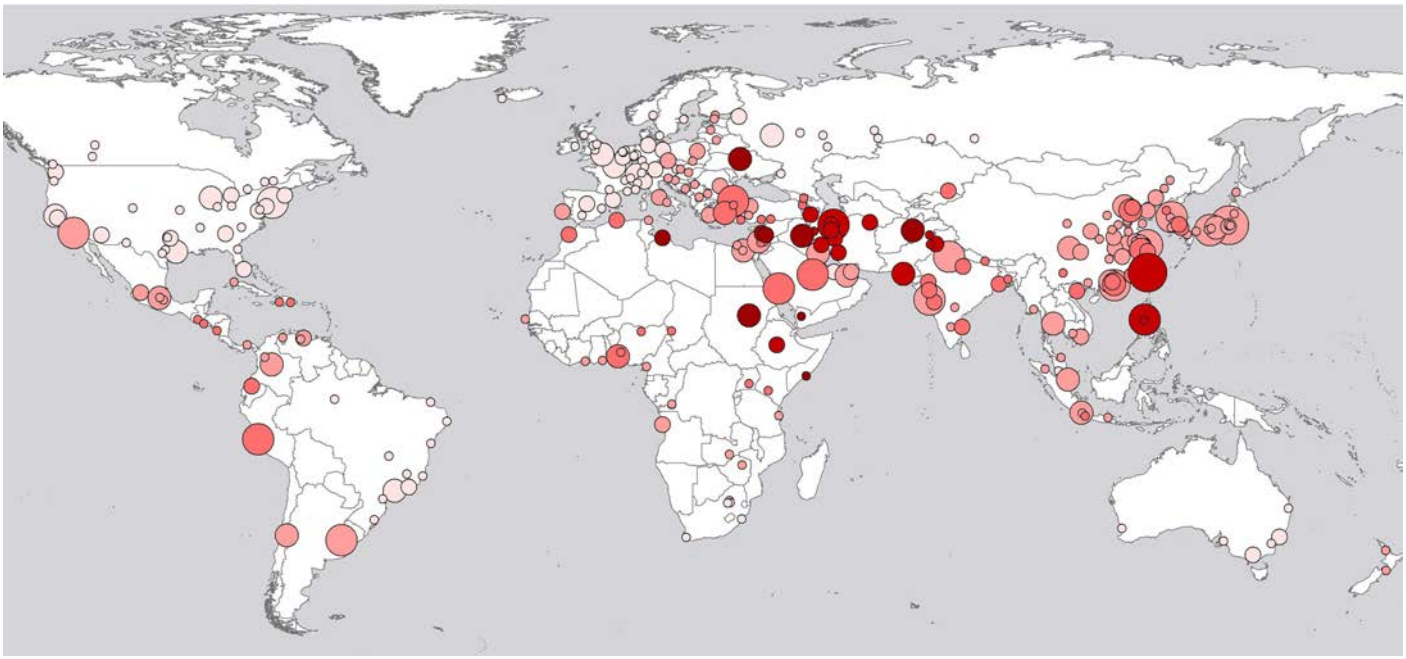


Figure 2: Total GDP@Risk from All Threats Combined showing Taipei and Tokyo as the world cities most at risk, 2015-2025

The results of this research can be used to assess the risk profiles of individual cities as well as gain a better understanding of how risk affects the global economy. The final map of the atlas (Figure 2) collection shows total GDP@Risk for the cities from all threats combined.

Figure 3 shows the top 50 cities ranked by their total GDP@Risk from all causes. This represents the expected loss (amount of GDP output loss that will result from a scenario, factored by the probability of that scenario occurring) for a city over the next ten years, from 1 Jan 2015 to 1 Jan 2025.

Taipei and Tokyo, which are both vulnerable to a wide combination of risks, including natural and man-made sit at the top of this table, with a combined GDP@Risk of over US$385bn. Inevitably, cities with higher GDP sit at the top of these tables – they have more wealth to lose. However, Figure 4 shows these figures represented as a percentage of the cities' GDP and here we see some differences in the results – with the two top cities, Manila and Rosario both in the Philippines and primarily affected by natural catastrophe losses (wind storm and earthquake, predominantly). This chart shows how less wealthy countries are more vulnerable to losing a higher proportion of their economy, and are particularly vulnerable to natural catastrophe risk due to a combination of less advanced infrastructure and low levels of insurance penetration.

The uncertainties in the analysis make it difficult to place great reliance on the exact ranking order of the cities. However, the list is quite stable in terms of the tiers of risk which the various cities occupy. Changing assumptions within plausible ranges in the individual risk models may change the ordering of the cities by some ranks, but generally does not reallocate cities from one tier to another, so the tiering can be considered fairly robust.

The risk profile of each city varies greatly. Each city has its own set of threats and potential for economic disruption from different types of threat and these "risk scoresheets" can be seen in Table 1.

Natural catastrophe risk drives localised risk differences between cities, with windstorm being a major threat to many of the cities in the top tiers, and the threat of earthquake as an important component of the risk for six out of the top 10 cities. Financial crises and disease threats are more general and less localised, reflecting the connectivity and interrelation of how these threats affect entire regions and financial flows.

Rank	City Name	Country	GDP@Risk ($US Bn)
1	Taipei	Taiwan	202
2	Tokyo	Japan	183
3	Seoul	Republic of Korea	137
4	Manila	Philippines	114
5	Tehran	Iran	109
6	Istanbul	Turkey	106
7	New York	United States	91
8	Osaka	Japan	91
9	Los Angeles	United States	91
10	Shanghai	China	88
11	Hong Kong	Hong Kong	88
12	Buenos Aires	Argentina	86
13	Bombay (Mumbai)	India	81
14	Delhi	India	77
15	Lima	Peru	73
16	Sao Paulo	Brazil	63
17	Paris	France	56
18	Beijing	China	55
19	Mexico City	Mexico	54
20	London	United States	54
21	Moscow	Russia	54
22	Singapore	Singapore	51
23	Tianjin	China	50
24	Guangzhou	China	50
25	Tel Aviv Jaffa	Israel	49
26	Kabul	Afghanistan	49
27	Kuwait City	Kuwait	49
28	Bangkok	China	49
29	Chengtu	China	49
30	Karachi	Pakistan	49
31	Shenzhen	China	48
32	Khartoum	Sudan	47
33	Hangzhou	China	46
34	Jeddah	Saudi Arabia	46
36	Riyadh	Saudi Arabia	44
37	Chicago	United States	43
38	San Francisco	United States	42
39	Dongguan, Guangdong	China	42
40	Jakarta	Indonesia	41
41	Berne	Switzerland	38
42	Kiev	Ukraine	37
43	Izmir	Turkey	35
44	Cairo	Egypt	34
45	Nagoya	Japan	32
46	Houston	United States	32
47	Bogotá	Colombia	31
48	Santiago	Chile	31
49	Lagos	Nigeria	31
50	Calcutta	India	30

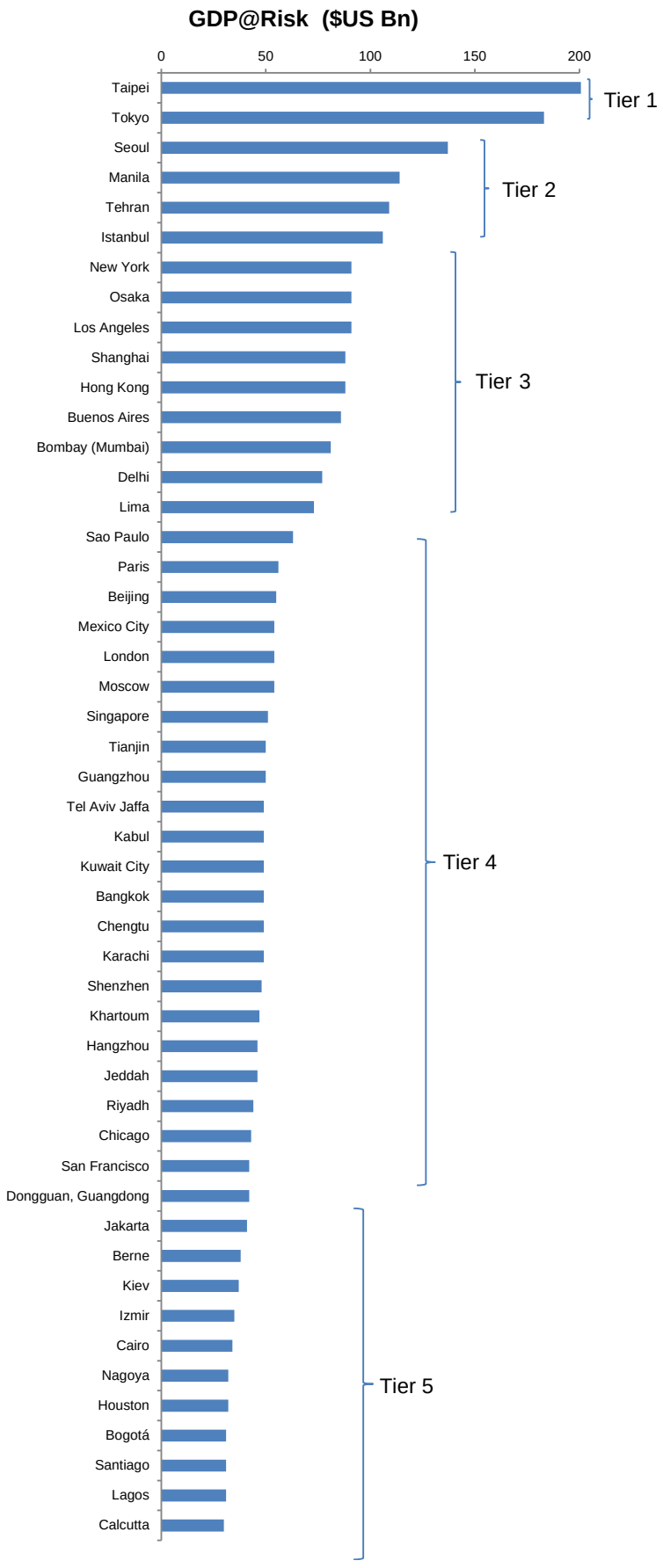


Figure 3: Top 50 cities ranked by nominal GDP@Risk, 2015-2025

Rank	City Name	Country	GDP@Risk ($US Bn)
1	Manila	Philippines	5.0%
2	Rosario	Philippines	4.9%
3	Taipei	Taiwan	4.5%
4	Xiamen	China	4.2%
5	Kabul	Afghanistan	4.1%
6	Port au Prince	Haiti	3.6%
7	Kathmandu	Nepal	3.3%
8	Santo Domingo	Dominican Republic	3.3%
9	Ningbo	China	3.2%
10	Hangzhou	China	3.2%
11	Guangdong	China	3.1%
12	Quito	Peru	3.1%
13	Tehran	Iran	3.0%
14	Managua	Nicaragua	2.8%
15	Guatemala City	Guatemala	2.8%
16	Calcutta	India	2.8%
17	Damascus	Syria	2.8%
18	Hanoi	Vietnam	2.5%
19	Sana'a	Yemen	2.5%
20	Beirut	Lebanon	2.5%
21	Tangshan	China	2.5%
22	Kunming	China	2.5%
23	Busan	Republic of Korea	2.4%
24	Yerevan	Armenia	2.3%
25	Qom	Iran	2.3%
26	Daegu	Republic of Korea	2.3%
27	Baghdad	Iraq	2.3%
28	Izmir	Turkey	2.3%
29	Almaty	Kazakhstan	2.2%
30	Ahvaz	Iran	2.2%
31	San Salvador	El Salvador	2.2%
32	Mogadishu	Somalia	2.2%
33	Havana	Cuba	2.2%
34	Shiraz	Iran	2.1%
36	Karaj	Iran	2.1%
37	Kermanshah	Iran	2.1%
38	Daejon	Republic of Korea	2.1%
39	Gwangju	Republic of Korea	2.1%
40	Changzhou	China	2.1%
41	Nanning	China	2.1%
42	Bandung	Indonesia	2.1%
43	Tabriz	Iran	2.1%
44	Addis Abeba	Ethiopia	2.1%
45	Lima	Peru	2.0%
46	Suzhou	China	2.0%
47	Adana	Turkey	1.9%
48	Wuxi	China	1.9%
49	Islamabad	Pakistan	1.8%
50	Tianjin	China	1.8%

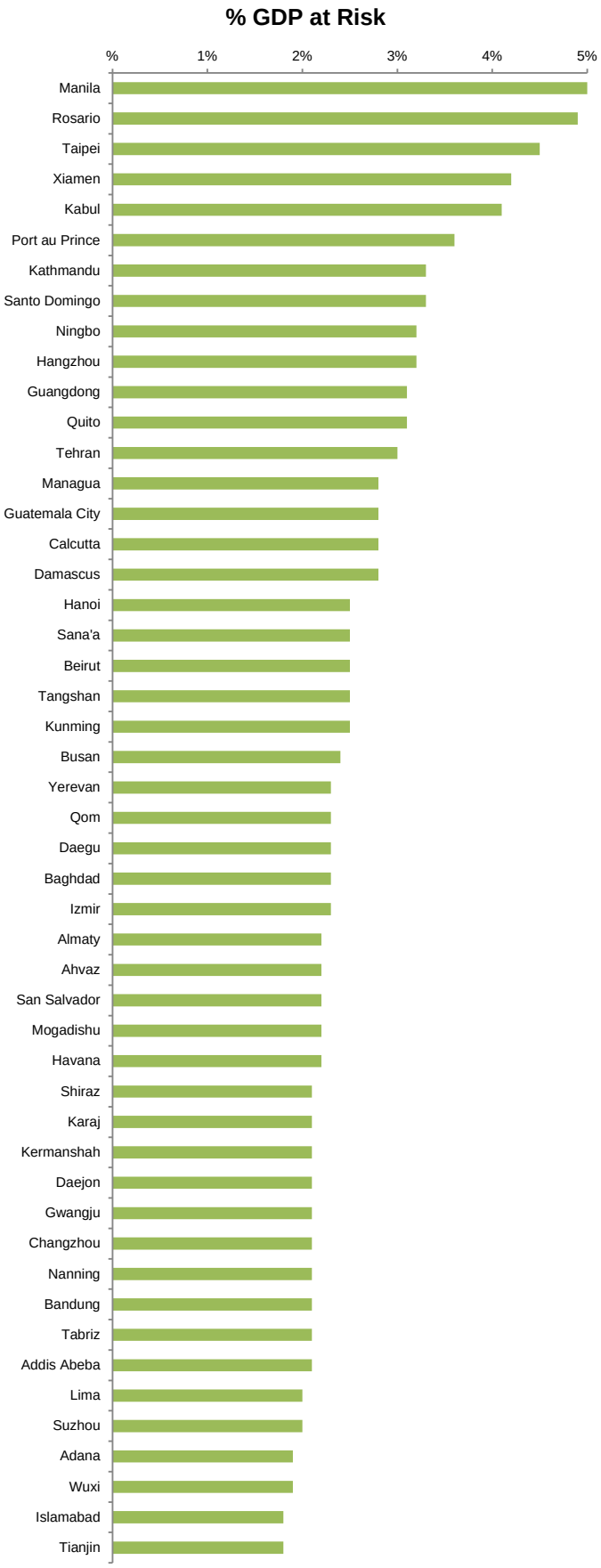


Figure 4: Top 50 cities ranked by percentage of GDP@ Risk, 2015-2025

Rank [Total GDP at Risk]	1	2	3	4	5	6	7	8	9	10
CRS City ID	TWN_5155	JPN_KNT	KOR_SJK	PHL_NCR	IRN_TER	TUR_IST	USA_NYO	JPN_KIN	USA_CAL	CHN_SHN
City Name	Taipei	Tokyo	Seoul	Manila	Tehran	Istanbul	New York	Osaka	Los Angeles	Shanghai
CRS Country ID	TWN	JPN	KOR	PHL	IRN	TUR	USA	JPN	USA	CHN
Country Name	Taiwan, Province of Ch	Japan	Korea, Republic of	Philippines	Iran, Islamic Republic of	Turkey	United States	Japan	United States	China
Earthquake	14.72%	10.28%	0.00%	11.66%	31.85%	28.43%	0.05%	8.22%	20.09%	0.00%
Volcano	3.49%	4.94%	0.62%	5.09%	0.00%	0.00%	0.00%	3.95%	0.00%	0.98%
Wind Storm	40.25%	15.87%	32.73%	53.21%	0.00%	0.00%	0.00%	20.25%	0.00%	30.41%
Temperate Wind Storm	0.00%	0.00%	0.00%	0.00%	0.23%	0.00%	3.26%	0.00%	1.67%	0.00%
Flooding	5.33%	9.64%	7.20%	4.79%	2.37%	5.17%	14.32%	15.18%	14.63%	11.17%
Tsunami	0.00%	2.05%	0.00%	0.45%	0.00%	0.00%	0.00%	1.64%	0.59%	0.00%
Drought	0.39%	1.57%	4.46%	1.63%	1.73%	1.82%	0.00%	1.26%	4.22%	2.10%
Freeze	0.00%	0.72%	1.04%	0.00%	0.00%	0.00%	2.57%	0.00%	0.00%	0.00%
Heatwave	0.00%	0.36%	0.00%	0.00%	0.00%	0.21%	1.30%	0.29%	0.41%	0.59%
Market Crash	14.18%	12.51%	9.25%	4.20%	5.49%	8.07%	27.55%	10.00%	21.21%	12.24%
Sovereign Default	0.11%	0.41%	1.48%	0.63%	8.98%	10.22%	0.60%	0.33%	0.46%	0.39%
Oil Price	3.85%	11.68%	9.32%	2.09%	-3.78%	9.03%	17.24%	9.34%	13.28%	6.37%
Interstate War	10.05%	16.16%	24.12%	11.08%	37.93%	12.78%	0.54%	12.92%	0.41%	1.26%
Separatism	0.00%	0.00%	0.00%	0.00%	6.47%	5.83%	0.00%	0.00%	0.00%	9.86%
Terrorism	0.00%	0.12%	0.14%	0.67%	2.39%	1.94%	0.65%	0.09%	0.06%	0.08%
Social Unrest	0.07%	0.11%	0.07%	0.25%	0.26%	3.31%	0.44%	0.02%	0.15%	0.17%
Electrical power outage	0.61%	1.24%	0.74%	0.41%	0.58%	1.08%	1.83%	0.99%	1.41%	1.24%
Cyber	2.55%	3.33%	1.98%	0.25%	0.46%	2.18%	15.43%	8.30%	11.88%	2.43%
Solar Storm	0.30%	1.32%	0.79%	0.27%	0.31%	0.77%	2.48%	1.06%	1.64%	0.89%
Nuclear Power Plant Accident	0.28%	0.16%	0.00%	0.00%	0.00%	0.00%	1.56%	0.13%	0.00%	0.11%
Pandemic	3.52%	6.72%	5.58%	3.06%	4.32%	8.68%	9.00%	5.38%	6.96%	16.45%
Plant Epidemic	0.29%	0.81%	0.48%	0.25%	0.42%	0.47%	1.19%	0.64%	0.92%	3.28%
Total GDP at Risk ($US Bn)	201.62	183.07	136.52	114.02	108.50	105.65	91.25	91.11	90.84	88.15

Rank [Total GDP at Risk]	11	12	13	14	15	16	17	18	19	20
CRS City ID	HKG_HKG	ARG_DFD	IND_BOM	IND_DEL	PER_LIM	BRA_SEP	FRA_IDF	CHN_BJN	MEX_DTD	GBR_LON
City Name	Hong Kong	Buenos Aires	Bombay (Mumbai)	Delhi	Lima	Sao Paulo	Paris	Beijing	Mexico City	London
CRS Country ID	CHN	ARG	IND	IND	PER	BRA	FRA	CHN	MEX	GBR
Country Name	Hong Kong	Argentina	India	India	Peru	Brazil	France	China	Mexico	United Kingdom
Earthquake	0.00%	0.00%	0.22%	0.22%	48.88%	0.00%	0.00%	13.91%	10.97%	0.00%
Volcano	0.00%	0.00%	0.00%	0.00%	0.62%	0.00%	0.00%	0.00%	21.56%	0.00%
Wind Storm	17.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	30.24%	0.00%
Temperate Wind Storm	0.00%	0.00%	1.41%	0.62%	0.00%	0.00%	1.50%	1.30%	0.00%	2.06%
Flooding	7.48%	8.57%	7.54%	14.65%	4.83%	18.36%	14.74%	7.43%	10.35%	18.01%
Tsunami	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Drought	2.80%	2.43%	0.00%	0.00%	0.00%	0.00%	0.00%	2.77%	0.00%	5.20%
Freeze	0.00%	0.00%	0.00%	0.45%	0.00%	0.00%	1.10%	1.54%	0.68%	1.00%
Heatwave	0.00%	0.00%	0.23%	0.23%	0.20%	0.00%	1.35%	0.00%	0.34%	0.51%
Market Crash	16.36%	7.18%	7.57%	7.44%	24.39%	24.14%	28.35%	16.16%	11.79%	26.12%
Sovereign Default	0.51%	14.53%	2.03%	1.99%	1.51%	3.40%	0.63%	0.51%	2.65%	0.51%
Oil Price	8.49%	7.38%	7.45%	7.32%	-7.84%	12.08%	17.85%	8.41%	-13.47%	16.34%
Interstate War	1.65%	40.34%	19.20%	18.88%	12.25%	0.00%	0.56%	1.66%	0.00%	0.51%
Separatism	12.95%	0.00%	20.69%	20.35%	0.00%	0.00%	0.00%	13.04%	0.00%	0.00%
Terrorism	0.10%	0.35%	9.81%	2.90%	3.50%	1.39%	1.18%	0.10%	1.04%	1.08%
Social Unrest	0.45%	0.88%	1.61%	3.57%	0.16%	0.64%	1.74%	1.00%	1.07%	0.41%
Electrical power outage	1.66%	1.92%	2.37%	2.33%	1.02%	2.36%	1.89%	1.64%	2.33%	1.73%
Cyber	1.72%	2.52%	3.78%	3.71%	0.72%	14.41%	15.88%	3.21%	5.88%	14.63%
Solar Storm	1.10%	1.03%	0.79%	0.83%	0.68%	1.56%	2.21%	1.17%	1.16%	2.19%
Nuclear Power Plant Accident	0.94%	0.13%	0.67%	0.10%	0.00%	0.21%	0.25%	0.07%	0.00%	0.23%
Pandemic	21.61%	12.29%	14.12%	13.90%	8.45%	20.00%	9.88%	21.76%	12.32%	8.66%
Plant Epidemic	4.37%	0.46%	0.51%	0.50%	0.64%	1.47%	0.90%	4.33%	1.09%	0.82%
Total GDP at Risk ($US Bn)	87.72	85.60	80.99	76.96	72.69	63.36	56.23	55.10	54.04	53.92

Rank [Total GDP at Risk]	21	22	23	24	25	26	27	28	29	30
CRS City ID	RUS_MSC	SGP_SGP	CHN_TJ	CHN_GUZ	ISR_TAV	AFG_KAB	KWT_KUW	THA_KTH	CHN_SCH	PAK_KAR
City Name	Moscow	Singapore	Tianjin	Guangzhou	Tel Aviv_Jaffa	Kabul	Kuwait City	Bangkok	Chengtu	Karachi
CRS Country ID	RUS	SGP	CHN	CHN	ISR	AFG	KWT	THA	CHN	PAK
Country Name	Russian Federation	Singapore	China	China	Israel	Afghanistan	Kuwait	Thailand	China	Pakistan
Earthquake	0.00%	0.00%	41.41%	0.00%	3.02%	8.43%	7.24%	0.00%	13.80%	5.72%
Volcano	0.00%	7.17%	0.00%	0.00%	0.00%	0.17%	0.00%	1.13%	0.00%	0.44%
Wind Storm	0.00%	0.00%	0.00%	31.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Temperate Wind Storm	0.00%	1.20%	0.89%	0.00%	0.00%	0.11%	0.00%	1.36%	1.28%	0.64%
Flooding	3.50%	11.49%	5.10%	7.83%	3.52%	0.60%	7.46%	10.63%	9.77%	0.14%
Tsunami	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Drought	0.00%	1.92%	1.90%	2.19%	1.22%	0.34%	2.69%	2.90%	2.74%	0.00%
Freeze	3.14%	0.00%	1.05%	0.50%	0.00%	0.19%	0.00%	0.00%	0.63%	0.00%
Heatwave	0.66%	0.00%	0.00%	0.25%	0.00%	0.00%	0.31%	0.00%	0.32%	0.10%
Market Crash	33.32%	34.55%	11.07%	12.80%	22.43%	2.28%	46.46%	42.28%	15.93%	10.00%
Sovereign Default	4.95%	0.46%	0.35%	0.40%	0.95%	4.68%	0.40%	2.48%	0.50%	5.71%
Oil Price	-29.35%	19.04%	5.76%	6.66%	6.02%	1.02%	-15.37%	10.80%	8.30%	2.74%
Interstate War	2.22%	0.00%	1.14%	1.32%	45.24%	56.60%	35.66%	0.00%	1.65%	53.40%
Separatism	20.86%	0.00%	8.96%	10.34%	11.78%	7.26%	0.00%	0.00%	12.95%	8.40%
Terrorism	11.25%	0.14%	0.07%	0.08%	0.80%	13.65%	0.19%	1.86%	0.10%	3.62%
Social Unrest	2.05%	0.14%	0.15%	0.18%	0.44%	0.61%	0.98%	5.26%	0.22%	0.73%
Electrical power outage	3.35%	2.27%	1.12%	1.30%	0.72%	0.27%	1.59%	1.72%	1.62%	0.71%
Cyber	12.81%	6.67%	2.20%	2.54%	0.45%	0.00%	0.93%	2.18%	3.16%	0.20%
Solar Storm	3.04%	1.51%	0.80%	0.86%	0.51%	0.14%	1.14%	1.14%	1.15%	0.35%
Nuclear Power Plant Accident	0.00%	0.00%	0.10%	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Pandemic	27.12%	12.44%	14.96%	17.26%	2.58%	3.35%	9.82%	11.72%	21.61%	6.22%
Plant Epidemic	1.06%	0.99%	2.97%	3.43%	0.31%	0.31%	0.51%	4.53%	4.27%	0.84%
Total GDP at Risk ($US Bn)	53.52	51.18	50.24	49.56	49.48	49.05	49.04	49.04	48.86	48.79

Rank [Total GDP at Risk]	31	32	33	34	35	36	37	38	39	40
CRS City ID	CHN_SHE	SDN_AKH	CHN_Hang	SAU_JED	IRQ_BGH	SAU_ARI	USA_ILL	USA_FRA	CHN_82927	IDN_JRA
City Name	Shenzhen	Khartoum	Hangzhou	Jeddah	Baghdad	Riyadh	Chicago	San Francisco	)ongguan, Guangdon	Jakarta
CRS Country ID	CHN	SDN	CHN	SAU	IRQ	SAU	USA	USA	CHN	IDN
Country Name	China	Sudan	China	Saudi Arabia	Iraq	Saudi Arabia	United States	United States	China	Indonesia
Earthquake	0.00%	0.00%	0.00%	9.19%	0.00%	0.00%	0.00%	13.62%	0.00%	13.06%
Volcano	0.00%	0.28%	0.00%	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%	9.87%
Wind Storm	30.96%	0.00%	62.26%	0.00%	0.00%	0.00%	0.00%	0.00%	63.47%	0.00%
Temperate Wind Storm	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.22%	1.33%	0.00%	1.01%
Flooding	7.87%	1.17%	6.11%	0.26%	1.58%	0.17%	14.59%	13.15%	4.18%	7.86%
Tsunami	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.11%
Drought	2.21%	0.00%	1.15%	0.00%	0.00%	0.00%	0.00%	2.13%	1.17%	7.66%
Freeze	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%	2.62%	0.00%	0.27%	0.00%
Heatwave	0.26%	0.06%	0.13%	0.30%	0.05%	0.32%	1.33%	0.00%	0.14%	0.00%
Market Crash	12.86%	3.80%	6.67%	44.78%	3.05%	47.65%	28.07%	25.30%	6.74%	14.50%
Sovereign Default	0.41%	6.84%	0.21%	0.41%	5.71%	0.43%	0.61%	0.56%	0.22%	19.28%
Oil Price	6.69%	-2.66%	3.48%	-14.58%	-2.41%	-15.51%	17.57%	15.85%	3.54%	-16.76%
Interstate War	1.32%	75.41%	0.69%	38.63%	64.74%	41.06%	0.55%	0.50%	0.72%	0.00%
Separatism	10.40%	5.76%	5.43%	0.00%	8.82%	0.00%	0.00%	0.00%	5.64%	0.00%
Terrorism	0.08%	3.01%	0.04%	5.22%	12.84%	9.54%	0.07%	0.07%	0.04%	10.31%
Social Unrest	0.18%	0.19%	0.09%	0.41%	1.70%	0.99%	0.20%	0.18%	0.09%	0.30%
Electrical power outage	1.30%	0.61%	0.68%	1.51%	0.33%	1.61%	1.86%	1.68%	0.69%	1.91%
Cyber	2.55%	0.01%	1.33%	0.54%	0.01%	0.57%	15.72%	14.17%	1.34%	3.86%
Solar Storm	0.87%	0.20%	0.48%	1.00%	0.18%	1.07%	2.53%	1.96%	0.46%	1.27%
Nuclear Power Plant Accident	0.74%	0.00%	0.39%	0.00%	0.00%	0.00%	1.59%	0.00%	0.06%	0.00%
Pandemic	17.36%	3.74%	9.06%	10.94%	3.31%	11.61%	9.25%	8.42%	9.42%	18.69%
Plant Epidemic	3.44%	1.59%	1.79%	0.48%	0.08%	0.51%	1.21%	1.09%	1.82%	5.05%
Total GDP at Risk ($US Bn)	47.83	47.43	46.46	45.93	45.77	44.43	42.67	41.63	41.51	41.42

Table 1: Drivers of expected loss by each city for the top 40 cities

A shift in the geography of risk

The patterns of GDP@Risk for different threats, and the final summary map of total GDP@Risk from all threats combined, shows that the threat to the world's economic growth is most significant in the emerging markets of:

- Southeast Asia;
- Middle East;
- Latin America;
- Indian Subcontinent.

Table 2: Number of cities in top ranks by region

		Number of cities in	
		Top 20	Top 50
China		3	9
Japan		2	3
Rest of SE Asia		3	6
	SE Asia, Total	8	18
Middle East		2	9
Latin America		4	6
Indian Subcontinent		2	4
North America		2	5
Western Europe		2	3
Africa		0	2
Eastern Europe		0	3
Oceania		0	0

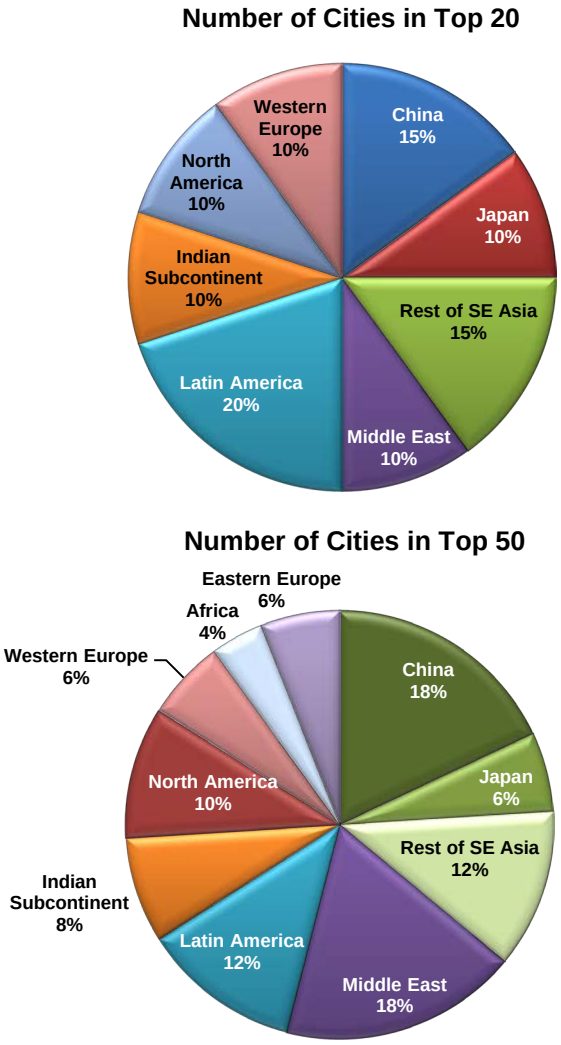


Figure 5: Number of cities in top ranking lists by region

This is a shift from historical patterns of loss, which have traditionally shown North America and Europe most at risk, representing the mature economic areas of high values of exposure. The projected growth of the cities in emerging markets indicates that exposure will increase in many areas that severely vulnerable to various catastrophes. In some cases, the growth of the markets in these new regions will, itself, generate further man-made threats, such as cyber-attack or social unrest.

Future catastrophe losses will occur in different geographical regions than they have historically. These regions may be unprepared for the scale of loss and have less developed market mechanisms for risk transfer, protection, and recovery processes, and could benefit from the experience of mature risk transfer markets.

The fact that these regions will be growing rapidly over the next decade and investing in new infrastructure and economic systems provides an opportunity to introduce more resilient facilities and to mitigate the impact of these crises when they occur. The World Economic Forum (WEF) estimates that global spending on basic infrastructure—such as transport, power, water and communications—currently amounts to $2.7 trillion a year.[1] Ensuring that future investments in infrastructure provide a quality that can be resilient to the threats that they are likely to face, will reduce the economic risk described here.

Total risk by threat

Figure 6 shows the total GDP@Risk as a combined value from all 300 cities, for each threat. This shows the relativities between different threats.

The top seven threats account for three quarters of the total GDP damage across the 300 World Cities. By itself, Financial Crisis accounts for 20% of GDP@Risk, with Interstate War constituting 15% of the risk. Four threats of similar magnitude, Human Pandemics, Windstorm, Earthquake and Flood, comprise the next tier of most damaging threats.

[1] World Economic Forum, May 2013 Industry Agenda, *Strategic Infrastructure; Steps to Prepare and Accelerate Public-Private Partnerships*, p.14

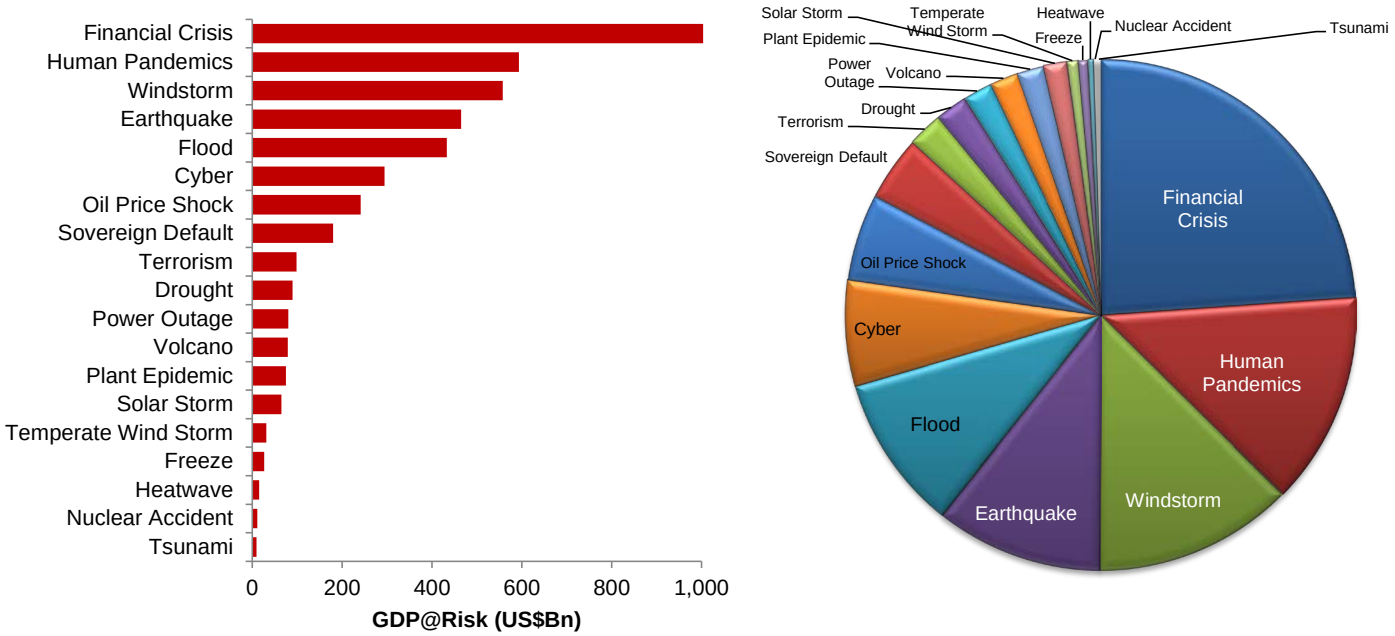


Figure 6: Comparison of risk by threat types; GDP@Risk combined from all cities for each threat

Cyber catastrophe risk is an additional 5% and rounds out the top 7 threats. Together the top seven threats make up 76% of GDP@Risk.

The other 15 threats that make up the remaining quarter of the risk add an important dimension to the complexity of the risk landscape and cannot be ignored, as they are significant drivers of risk in their own right for a number of high rank cities: oil price shock is the second largest driver of risk for New York, ranked seventh, sovereign default risk is the third largest driver of risk for Tehran, ranked fourth. Terrorism is the fourth largest driver of risk for Mumbai, ranked eleventh.

The top seven threats account for three quarters of the total GDP damage across the 300 World Cities. By itself, Financial Crisis accounts for 20% of GDP@Risk, with War constituting 15% of the risk. Four threats of similar magnitude, Human Pandemics, Windstorm, Earthquake and Flood, comprise the next tier of most damaging threats. Cyber catastrophe risk is an additional 5% and rounds out the top 7 threats. Together the top seven threats make up 76% of GDP@Risk.

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A catastrophe burden of 1.5% on world growth

The analysis suggests that the expected loss (probability-weighted losses) from the sum value of additive risks will amount to $5.4 trillion for these 300 cities from 1 Jan 2015 to 1 Jan 2025. The total GDP projected to be generated from the 300 cities 2015-2025 is $373 trillion, so the expected loss from catastrophes is 1.5% of total projected GDP output. Economists such as Oxford Economics estimate that the world's economy will average 3.2% growth for the next decade. This expected catastrophe loss amounts to about half of the expected global growth rate.

The projections for future growth are based on models of past progress which incorporate actual catastrophe losses. It is very difficult to estimate the counter-factual effect of what past economic growth would have been without the wars, financial crises, epidemics, and all the other shocks that have slowed progress, but this analysis suggests that catastrophes put a burden of 1.5% on the world's economic output. If catastrophe losses didn't occur, economic growth would be significantly higher.

Mitigation of catastrophe losses is an investment that could potentially yield an enormous benefit in perpetuity if by investing in more resilient institutions and stronger infrastructure, the burden on economic growth were reduced. This is discussed further below.

These cities account for around 50% of global GDP today (and an estimated two thirds of global GDP by 2025). The rest of the world's GDP is distributed in many other locations and is not so concentrated,

so it is not straightforward to translate the expected losses from the 300 cities from these threats to the rest of the global economy. Simply factoring the $5.4 trillion from cities that represent 50% of the world's GDP today and 67% by 2025 would give a range of $7 to 10 trillion for the total global economy, but this is almost certainly an oversimplification.

Other observations

Traditionally, people have focused on natural catastrophes as the main threats to city prosperity. This analysis shows that there are more dimensions to the problem of catastrophic disruption to a city's economy than natural disasters alone. Figure 7 shows that less than a third of the expected loss to all of the cities will come from natural catastrophes. More than half of the future risk is from man-made threats – the financial shocks, human errors and conflicts. More than a third of future risks is from rapidly changing "emerging risks" – as shown in Figure 8.

This may change the way we think about risk in the future. Traditional natural catastrophes threatened the physical "means of production" (buildings and machinery). Threats to disruption of the social means of production – our networks, connections, trading relationships, and access to capital – is becoming significant and could become even more important over time.

Two-thirds of the risk is from threats that vary greatly from year to year – "dynamic threats." In this exercise, we have made our best projection of these for their average rate of occurrence over the next decade. However, a rigorous analysis of these risks could produce a different view next year. An annual review of risk would be likely to update a number of different aspects of this risk projection each year, including:

- this year's change in the ranking of cities;
- which threats have increased (or decreased);
- any progress in mitigation measures that are significantly reducing risk from catastrophe.

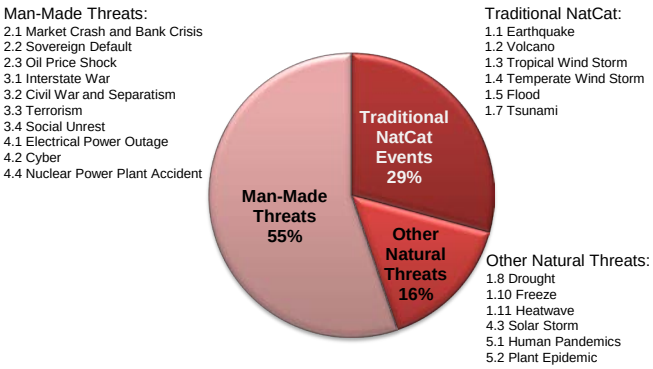


Figure 7: Breakdown of threats into natural catastrophe and man-made

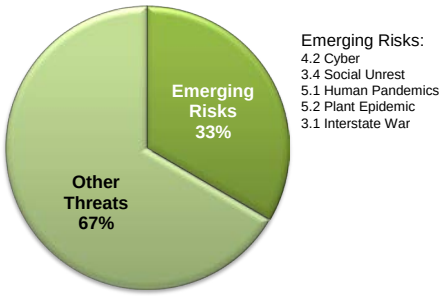


Figure 8: Total GDP@Risk from emerging threats

5 Validation

Comparison of modelled risk with historical costs for natural catastrophes

The modelled projection for GDP@Risk can be compared with historical costs of disasters, as a check on relativities between different threats. The EM-DAT Database of the Centre for Research on the Epidemiology of Disasters (CRED) is a catalogue of historical natural catastrophe events that contains estimates of costs and other impact metrics on 3,806 disasters since 1900. In Figure 9, we compare the direct costs from observed historical events over the past 100 years with our modeled estimates for the same threats for the economic losses that we expect might be generated over the next decade to our sample of 300 cities.

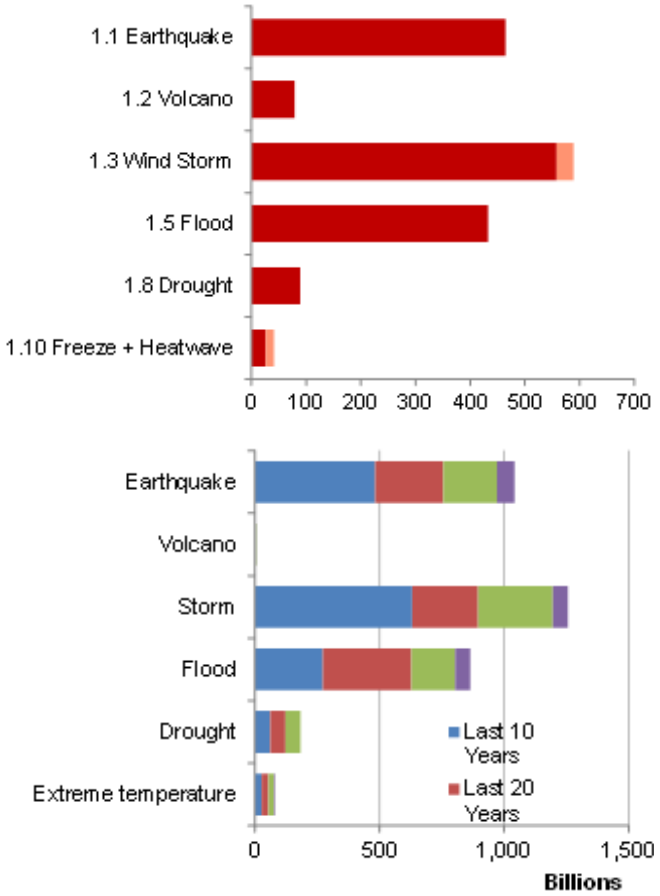


Figure 9: Comparison of modeled expected loss to GDP with historical direct costs of disasters, for selected natural catastrophe threats

The relativities of loss from different threats in the model are broadly consistent with the breakdown from past events, particularly in the ordering of largest to smallest. The relativities between threats are reasonably consistent across time periods, looking at the past 10 years, 20 years, 50 years and 100 years. Historically, over the past century windstorm losses are around 20% larger than earthquake losses and floods are about 17% less damaging than earthquakes. In the model, windstorm losses are 27% larger than earthquake and floods are 7% less than earthquake.

The model expects significant economic output loss from volcanic eruption, which is significantly greater relative to other threats, than the direct damage costs to physical infrastructure that volcanoes have caused historically.

Comparisons of economic output loss with costs of past damage to the built environment are not an exact equivalence for a validation test, but it provides indicative benchmarks to calibrate model parameterization.

Comparisons with other studies

A recent study by the US National Bureau of Economic Research makes a comparison of GDP erosion from cyclones with estimates of other threats (Hsiang and Jina, 2014). It uses a similar approach of lost GDP growth to estimate loss of income. Its main focus is on how repeated exposure to cyclone impacts has imposed an economic burden on countries exposed to them. They compare other threats with their estimate of cyclone income per capita. Table 3 compares their relativities of different threats, normalized to a cyclone loss of 1.0 and puts this alongside a similar set of comparable threats, normalized to the total GDP@Risk from tropical windstorm for our 300 cities as 1.0. It is not clear that the definitions of the different threats are exactly comparable, but the ranking and relativities are broadly consistent.

US NBER	National Income per capita Impact
Cyclone	1.00
Civil War	0.86
Currency Crisis	1.11
Banking Crisis	2.08

Cambridge Model	Global GDP@Risk
Tropical Windstorm	1.00
Separatism	0.45
Sovereign Default	0.32
Market Crash	1.88

Table 3: Comparison of study with US NBER estimation of economic impacts from different threats


Amsterdam, the Netherlands

Our modeled risk of sovereign default has much lower loss levels than the US NBER estimation of the loss of income resulting from a currency crisis, and our estimates of the costs of separatism are significantly lower than the NBER estimation of the cost of civil war.

Comparison with Swiss Re study of city risk

Swiss Re has developed the CatNet system that contains datasets on natural hazards and cities and published a study in 2013, which assesses 616 cities for 5 perils:

- Earthquake;
- Wind storm;
- River flood;
- Storm surge;
- Tsunami.[1]

The study uses "working days lost" as their metric of GDP loss, and also looks at the value of those working days in that city as a proportion of the national economy. The report identifies the impact of all combined perils on a top 10 set of metropolitan areas, with additional cities illustrated.[2]

The top 10 cities identified in our study, which includes additional threats to natural catastrophe, contains eight of the Swiss Re "Top 10" cities. The two studies broadly concur on the main natural catastrophe threats and the cities most at risk from each threat.

There are, however, several differences in the prioritization and mix of threats between the two studies. In the Swiss Re study, river flood is the dominant peril and river flood and storm surge are modelled separately. The Swiss Re study does not identify Seoul or Istanbul as being as high a risk as the Cambridge study. The Cambridge analysis does not have as high a risk value for Amsterdam.

[1] Swiss Re (2013) *Mind the Risk: A global ranking of cities under threat from natural disasters.*

[2] Fig. 8 of Swiss Re (2013) *Mind the Risk*, 19

6 Sensitivity studies

Reducing the vulnerability of cities

The model reflects the destruction of the built environment that would be caused by damaging threats – each city is graded into a physical vulnerability category according to the structural types, quality and strength of the building stock. When a threat scenario occurs that involves physical destruction – e.g., an earthquake – the vulnerability parameter for the city affects how much damage occurs and how severely the economy is shocked with the capital loss and disruption from physical asset loss.

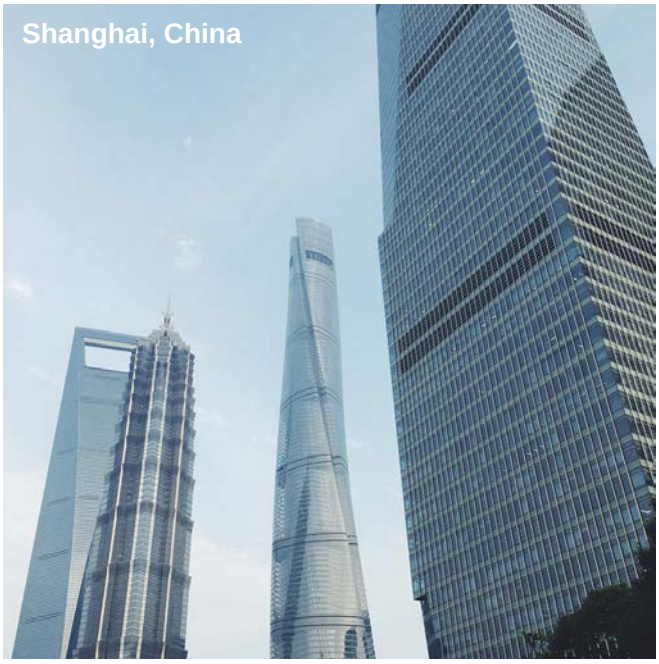
A sensitivity test for the model is to explore how the physical **vulnerability** parameter affects the loss estimation – how much our model assumes would be saved if the building stock were less damageable by the forces of the destructive threat.

Buildings that are engineered to withstand the destructive forces of winds, ground shaking, blast and water pressures are more expensive to construct and require social organization, building codes and compliance processes and checks. Countries that have good quality codes and high compliance are graded as level 1 – "Very Strong" in our vulnerability classification. It includes countries like New Zealand, Chile and United States, with a good tradition of engineering and an accepted level of investment in building high quality property and resilient infrastructure. Poorer quality countries have a lot of vernacular, artisan-constructed buildings, with low code compliance or checks.

These are rated as level 5 – "Very Weak" in our grading, and includes countries like Haiti that suffer very high levels of destruction in moderately strong earthquake shaking.

In Figure 10, a sensitivity test changes the ratings of all of the cities in our analysis, improving their vulnerability grading from their current level to the next stronger level, for example changing a city that is graded as level 4 to level 3.

If we re-run the model and change the vulnerability grading of all the cities in the world to the highest grading, i.e. all cities in the world all have the quality and robustness of buildings of New Zealand, then risk is reduced by 25%, as seen in Figure 11.


Shanghai, China

Raising the resilience of cities

If we re-run the model and change the vulnerability grading of all the cities in the world to the highest grading, i.e. all cities in the world all have the quality and robustness of buildings of New Zealand, then risk is reduced by 25%.

The results are similar when it comes to grading of social and economic resilience. **Resilience** is how the organization and social and economic structure of the cities improves how rapidly the city recovers after a catastrophe. We re-ran the model, increasing the resilience of certain cities - e.g., changing a city that is graded as level 4 to level 3. When we re-run the model with the cities assigned a better rating for social and economic resilience, it results in lower levels of GDP@Risk (Figure 12), because the cities recover more quickly from their catastrophe. The overall risk is reduced by about 12%.

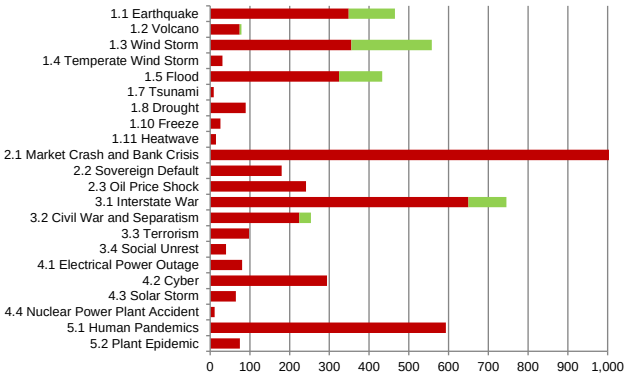
If we re-run the model and change the resilience grading of all the cities in the world to the highest grading (Figure 13), then risk is reduced by 25%.

If we re-run the model with all the cities being the highest possible grading of vulnerability and also being the highest grading of resilience, the overall risk is reduced by 54%.

The sensitivity tests suggest that over half of the risk would be reducible by managing the risk through improving the infrastructure and better organization and response.

		Examples	# of cities
1	Very Strong	Wellington, New Zealand; Los Angeles, USA	46
2	Strong	Frankfurt, Germany; Milan, Italy	59
3	Moderate	Sao Paulo, Brazil; Istanbul, Turkey	113
4	Weak	Bangkok, Thailand; Tripoli, Libya	68
5	Very Weak	Kampala, Uganda; Port au Prince, Haiti	18

		Examples	# of cities
1	Very Strong	Wellington, New Zealand; Los Angeles, USA; Frankfurt, Germany; Milan, Italy	105
2	Strong	Sao Paulo, Brazil; Istanbul, Turkey	113
3	Moderate	Bangkok, Thailand; Tripoli, Libya	68
4	Weak	Kampala, Uganda; Port au Prince, Haiti	18
5	Very Weak		0

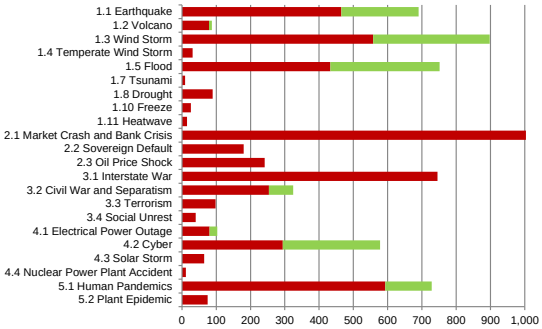


Was: $ 5.43 Tr
Now: $ 4.87 Tr
Saving: **$ 556 Bn**
Reduction **10%**

Figure 10: Sensitivity test reducing the physical vulnerability of all cities by one grade

		Examples	# of cities
1	Very Strong	Wellington, New Zealand; Los Angeles, USA	46
2	Strong	Frankfurt, Germany; Milan, Italy	59
3	Moderate	Sao Paulo, Brazil; Istanbul, Turkey	113
4	Weak	Bangkok, Thailand; Tripoli, Libya	68
5	Very Weak	Kampala, Uganda; Port au Prince, Haiti	18

		Examples	# of cities
1	Very Strong	All Cities	304
2	Strong		0
3	Moderate		0
4	Weak		0
5	Very Weak		0

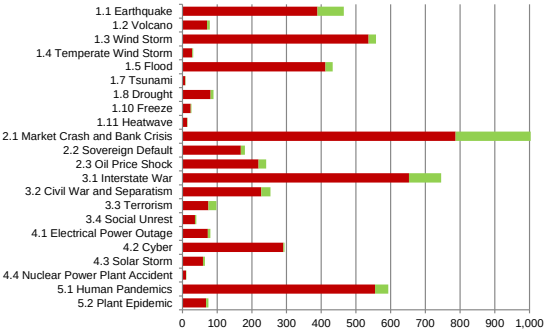


Was: $ 5.43 Tr
Now: $ 3.99 Tr
Saving: **$ 1.44 Tr**
Reduction **26%**

Figure 11: Sensitivity test reducing the physical vulnerability of all cities to the lowest vulnerability grade

		Examples	# of cities
1	Very Strong Resilience	UK, USA, Japan	21
2	Strong Resilience	Italy, Israel, UAE, China	13
3	Moderate Resilience	Turkey, South Africa, Brazil	28
4	Weak Resilience	Iran, Mexico, Vietnam	19
5	Very Weak Resilience	Sudan, Libya, Pakistan, Bangladesh	27

		Examples	# of cities
1	Very Strong Resilience	UK, USA, Japan + Italy, Israel, UAE, China	34
2	Strong Resilience	Turkey, South Africa, Brazil	28
3	Moderate Resilience	Iran, Mexico, Vietnam	19
4	Weak Resilience	Sudan, Libya, Pakistan, Bangladesh	27
5	Very Weak Resilience		0

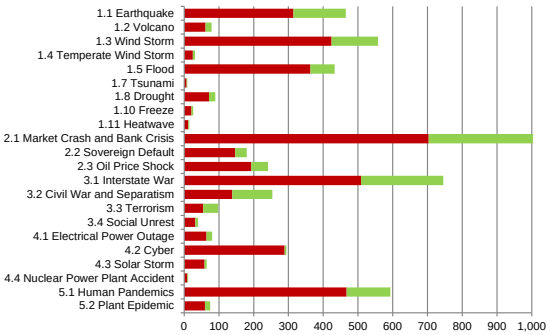


Was: $ 5.43 Tr
Now: $ 4.78 Tr
Saving: **$ 646 Bn**
Reduction **12%**

Figure 12: Sensitivity test improving the resilience of cities by one grade

		Examples	# of cities
1	Very Strong Resilience	UK, USA, Japan	21
2	Strong Resilience	Italy, Israel, UAE, China	13
3	Moderate Resilience	Turkey, South Africa, Brazil	28
4	Weak Resilience	Iran, Mexico, Vietnam	19
5	Very Weak Resilience	Sudan, Libya, Pakistan, Bangladesh	27

		Examples	# of cities
1	Very Strong Resilience	All countries	304
2	Strong Resilience		0
3	Moderate Resilience		0
4	Weak Resilience		0
5	Very Weak Resilience		0



Was: $ 5.43 Tr
Now: $ 4.02 Tr
Saving: **$ 1.41 Tr**
Reduction **26%**

Figure 13: Sensitivity test improving both the vulnerability and the social and economic resilience of all cities to the highest grades

Sensitivity of risk results to climate change

Climate Change is likely to increase the risk of:

- 1.3 Tropical Wind Storm;
- 1.4 Temperate Wind Storm;
- 1.5 Flood;
- 1.8 Drought;
- 1.10 Freeze;
- 1.11 Heatwave.

This sensitivity analysis tested how risk results might change with increasing frequency and severity of threats affected by climate change. For the climate change threats:

- All frequencies of these threats increased by 10%,
- All event severities increased by 5%

The results are shown in Figure 14 - global GDP@ Risk increases by $156 Billion, an increase of 3% on the total.

Some studies suggest that climate change could also increase the threat of

- 5.1 Human Pandemics;
- 5.2 Plant Epidemic;
- 3.4 Social Unrest;
- 3.1 Interstate War;
- 3.2 Civil War and Separatism.

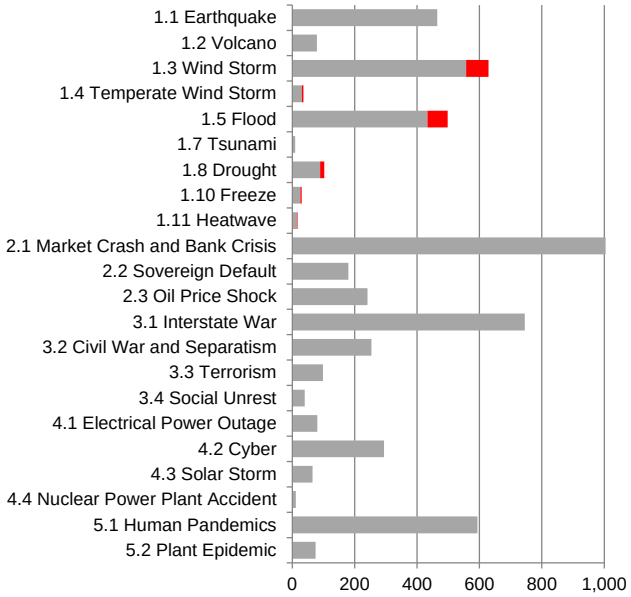


Figure 14: Climate Change sensitivity test

7 Conclusions

A decade of risk lies ahead. There is no reason to believe that the next ten years will have fewer shocks than any other decade in recent history. It won't always be a smooth ride to economic prosperity.

Managers of global businesses and the population who expect the current rate of economic progress to continue unabated need to be aware of the potential threats. Awareness is a key part of risk management.

It remains impossible to predict exactly when and where future catastrophes will occur, but patterns of risk – the "landscape of risk" – can be described and there is a major resource of scientific studies that contribute to the recognition of these patterns. The science of each separate threat tends to be in its own academic domain and studied in isolation. These studies become useful when collated and put into a single framework for comparison and analysis. This report is intended to make a useful contribution to this process.

It is necessary to be aware of the wide range of potential threats beyond natural catastrophes that could occur and will impact businesses and financial output.

This report suggests that the patterns of risk are changing – there is a shift in the geography of risk so that future losses might be expected more in Asia and the developing markets. The threats are themselves evolving, and we will see more disruption occurring from the emerging and man-made risks that affect our global social and economic network.

But this report also indicates that this risk is not inevitable or unavoidable. It shows that improvements and investment can change these losses. Improving the vulnerabilities of our cities can make a significant reduction in risk. Developing more resilience and faster recovery after a crisis has even more positive benefits. Overall, half of all the risk isolated in this study is reducible.

The landscape of city risk could look very different for future generations. Recognizing the risk - measuring it consistently, and mapping it out - is a key step in managing it. This report is a key step towards that objective.

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Research Project Team

World City Risk Project Leads
Simon Ruffle, *Director of Technology Research and Innovation*
Dr Andrew Coburn, *Director of External Advisory Board*

Cambridge Centre for Risk Studies Research Team
Professor Daniel Ralph, *Academic Director*
Dr Michelle Tuveson, *Executive Director*
Dr Andrew Coburn, *Director of External Advisory Board*
Simon Ruffle, *Director of Technology Research and Innovation*
Dr Scott Kelly, *Senior Research Associate*
Dr Olaf Bochmann, *Research Associate*
Dr Andrew Skelton, *Research Associate*
Dr Andrew Chaplin, *Risk Researcher*
Dr Jay Chan Do Jung, *Risk Researcher*
Eireann Leverett, *Risk Researcher*
Dr Duncan Needham, *Risk Researcher*
Edward Oughton, *Risk Researcher*
Dr Louise Pryor, *Risk Researcher*
Dr Ali Rais Shaghaghi, *Research Assistant*
Jennifer Copic, *Research Assistant*
Tamara Evan, *Research Assistant*
Jaclyn Zhiyi Yeo, *Research Assistant*

Consultants and Collaborators
Cytora Ltd., with particular thanks to Joshua Wallace and Andrzej Czapiewski
Cambridge Architectural Research Ltd., with particular thanks to Martin Hughes and Hannah Baker
Dr Gordon Woo, *RMS, Inc.*
Dr Helen Mulligan, *Director, Cambridge Architectural Research Ltd.*, and *co-founder Shrinking Cities International Research Network (SCiRN),*
Oxford Economics Ltd., with particular thanks to Nida Ali, *Economist*

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Website and Research Platform
http://www.risk.jbs.cam.ac.uk/

Cambridge Centre for Risk Studies
Cambridge Judge Business School
University of Cambridge
Trumpington Street
Cambridge
CB2 1AG

T: +44 (0) 1223 768386
F: +44 (0) 1223 339701
enquiries.risk@jbs.cam.ac.uk
www.risk.jbs.cam.ac.uk

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