Lloyds City Risk Index 2015-2025

August 2014

Methodology and Usage of City Economy Risk Analysis

Centre for Risk Studies

UNIVERSITY OF CAMBRIDGE
Judge Business School

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Lloyds City Risk Index 2015-2025

August 2014

Developing the City Risk Index

Centre for Risk Studies

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Andrew Coburn

Cambridge Centre for Risk Studies

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Acknowledgements

The Cambridge Centre for Risk Studies acknowledges the generous support provided for this research by Lloyd's

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Results and outputs of this research do not imply any endorsement by Lloyd's

Any errors and omissions are entirely those of the research team of the Cambridge Centre for Risk Studies

We acknowledge the generous support from all of the supporters of the Centre for Risk Studies for the development of the Cambridge Risk Framework, Catastronomics methodologies, and underlying datasets used in this analysis

Lloyd's City Risk Index 2015–2025

301 cities

18 threats

US$4.56trn at risk

Lloyd's City Risk Index 2015-2025 analyses the potential impact on the economic output (GDP@Risk) of 301 of the world's major cities from 18 manmade and natural threats.

Based on original research by the Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School, the Index shows that governments, businesses and communities are highly exposed to systemic, catastrophic shocks and must do more to mitigate

Explore

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What's Ground Breaking About this Study?

- This study looks at risk of economic output from catastrophes
  - Not just how catastrophes damage property
- It analyses cities as urban economic systems
  - Compiled profiles of the economies of 301 of the world's leading cities
- We have analyzed a wide range of catastrophe threats
  - Developed assessments of likelihood of 18 threat types impacting each city
  - In some cases, pioneered analysis of previously un-modelled threats
- Developed metrics for economic consequences of catastrophe
  - GDP@Risk
- Provided a framework for thinking about this problem
  - Identifying which cities and threats are most important

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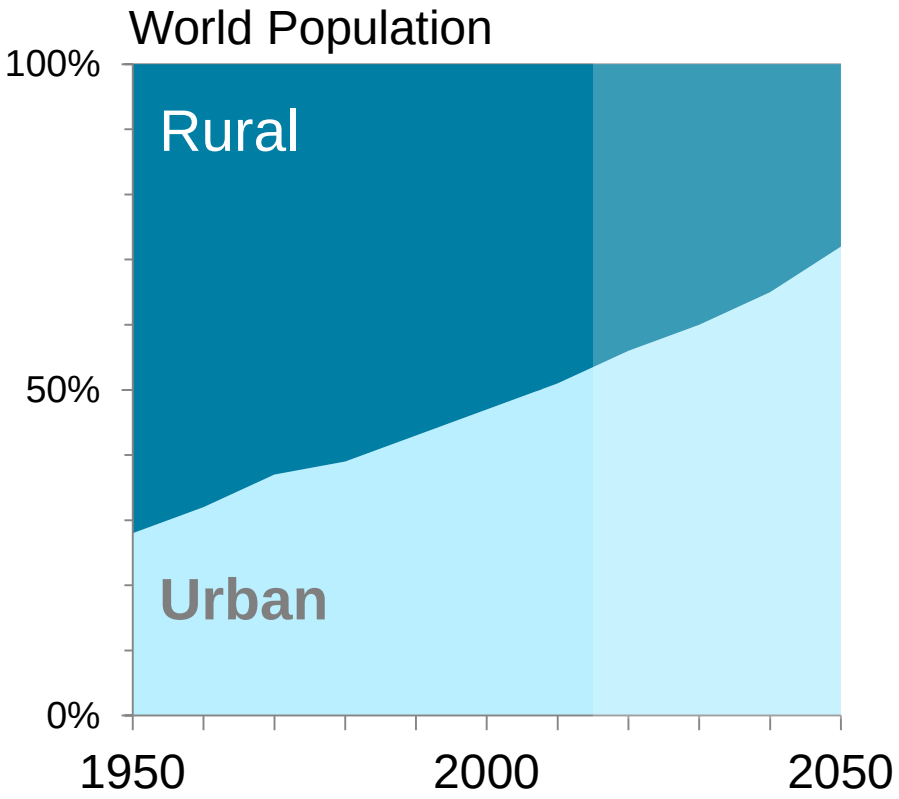
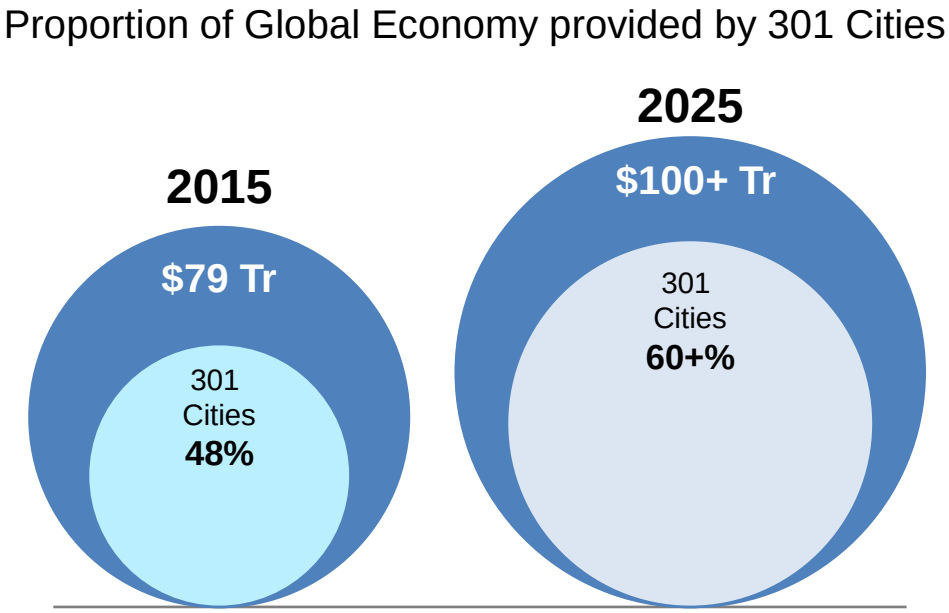
Cities and Economies

- A city economy is a system

The world's economy is increasingly urbanized





For example…

London economic region has increased its share of UK output from **15%** in 1960s to **45%** today

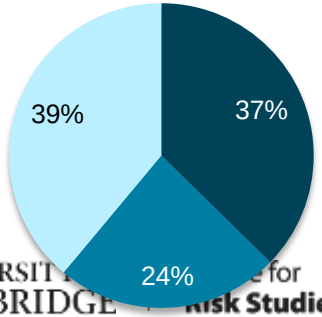
Towards the Knowledge Economy

Old

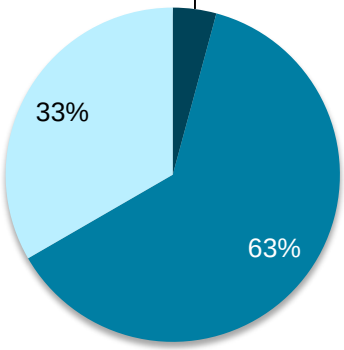
New

Cities economies categorized by type

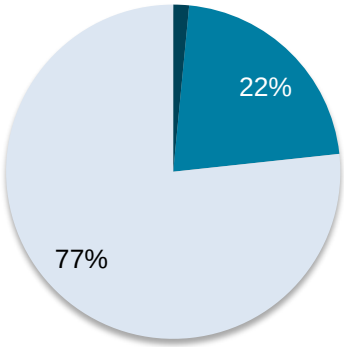
G: Agriculture with Industry & Service

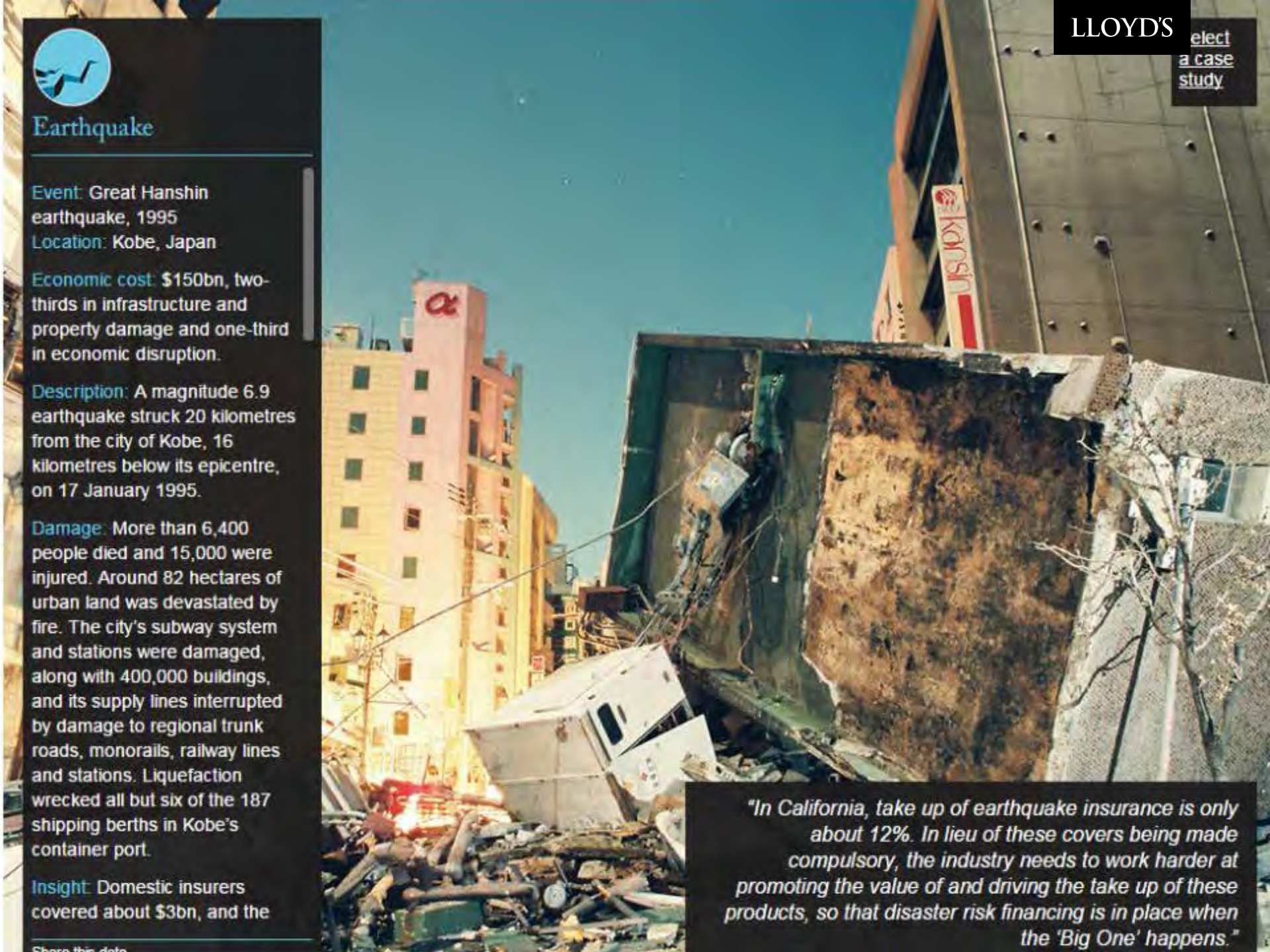


E: Industrial-Oriented Economy



A: Service-Dominated Economy





Earthquake

Event: Great Hanshin earthquake, 1995
Location: Kobe, Japan

Economic cost: $150bn, two-thirds in infrastructure and property damage and one-third in economic disruption.

Description: A magnitude 6.9 earthquake struck 20 kilometres from the city of Kobe, 16 kilometres below its epicentre, on 17 January 1995.

Damage: More than 6,400 people died and 15,000 were injured. Around 82 hectares of urban land was devastated by fire. The city's subway system and stations were damaged, along with 400,000 buildings, and its supply lines interrupted by damage to regional trunk roads, monorails, railway lines and stations. Liquefaction wrecked all but six of the 187 shipping berths in Kobe's container port.

Insight: Domestic insurers covered about $3bn, and the

"In California, take up of earthquake insurance is only about 12%. In lieu of these covers being made compulsory, the industry needs to work harder at promoting the value of and driving the take up of these products, so that disaster risk financing is in place when the 'Big One' happens."

Economic development hasn't all been smooth sailing

- The 301 cities have experienced many catastrophes over the past 50 years

Lost more than a million of their citizens to earthquakes

Seen a third or more of their economic capital wiped out by stock market crashes 5 times

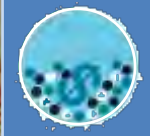
Experienced thousands of cyber attacks

Half of them have suffered a serious flood

A quarter of them have been flooded more than 5 times

32 cities have had to cope with a volcanic eruption less than 100 km away

Suffered more than 1,000 terrorist car bombs in city centres



Financial crisis of their governments defaulting on sovereign debts on 50 occasions

Had to combat the outbreak of a previously unknown disease five times

18 Threat Types

Finance and Trade


Market crash


Sovereign default


Oil price shock

Geopolitics and Society


Terrorism

Natural Catastrophe and Climate


Earthquake


Wind storm


Tsunami


Flood


Volcanic eruption


Drought


Freeze


Heatwave

Technology and Space


Nuclear accident


Power outage


Cyber attack


Solar storm

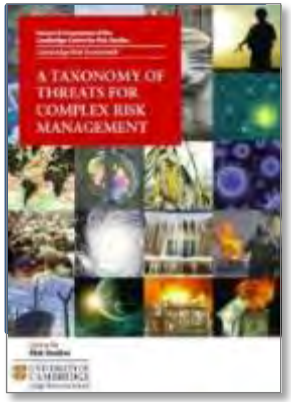
Health and Humanity


Human pandemic


Plant epidemic

Why are These the Threats to Worry About?

- Cambridge CRS has conducted an extensive review of potential causes of macroeconomic shocks
- We went through 1000 years of historical records to capture historical examples of shocks to society
- The review included
  A. Chronological Histories
  B. Disaster Catalogues
  C. Counter-factual evidence
  D. Scientific conjecture
  E. Peer review
  F. Other Approaches
- We developed a comprehensive Taxonomy of Threats
- This consists of 11 broad families of threat with around 50 threat types
- The 23 threats modelled here are from this taxonomy
- They represent the most important risks from the known threat universe



The Cambridge Centre for Risk Studies publication that describes the development of the Cambridge Threat Taxonomy

Available for Download from Website:
CambridgeRiskFramework.com

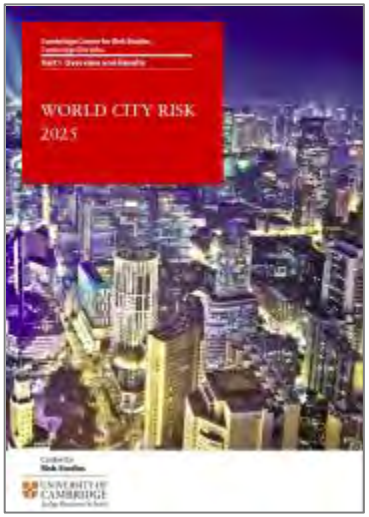
Putting them together into the City Risk Index

- For each city:

- We assess the threat of all 18 threat types
  - i.e. how likely that city is to experience a number of representative scenarios of different magnitudes from that threat (3 representative scenarios)
- We model the economic consequences of each scenario for the city
  - We have modelled 301 x 18 x 3 = **16,254** scenarios
- The GDP@Risk is the 'expected loss' – the loss x the probability
- We combine the GDP@Risk from the various threats and cities, assuming that the events are generally independent

Technical resources to help understand this

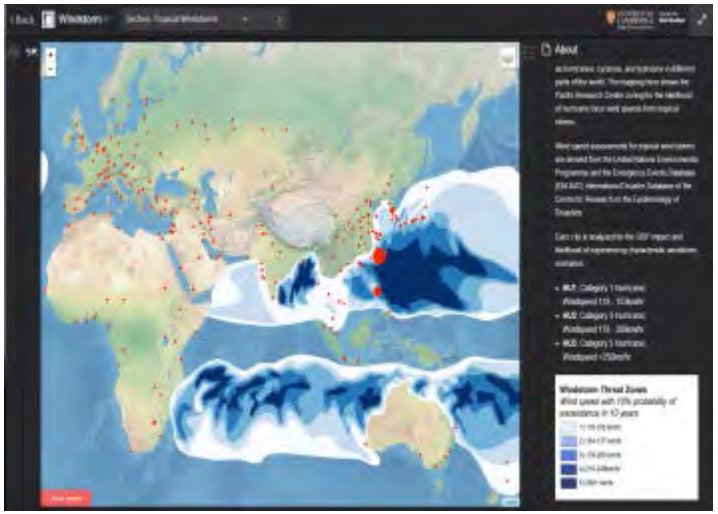
http://cambridgeriskframework.com/wcr



Methodology
Documentation

Presentations
and printable risk atlas

Threat
Observatory



Online interactive
threat maps

Cambridge Centre for Risk Studies – Risk Briefing

6 October 2015

Compiling the Data for Analysis

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Jaclyn Yeo

Cambridge Centre for Risk Studies

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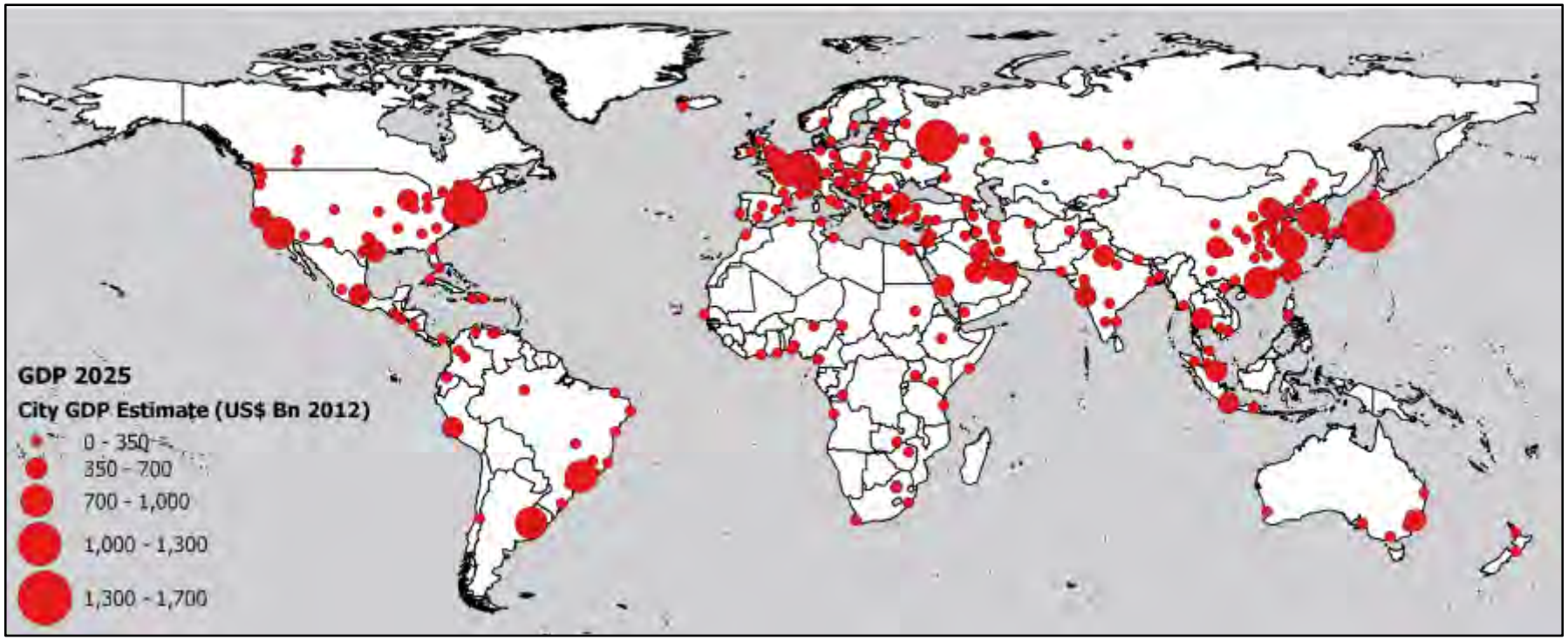
Modelling Threats for Every City

- Selecting the representative cities
  - Systematic review of cities at risk
- Identification of the authoritative science about each threat
  - Key data repository
- Quantification of the frequency and severity of each threat globally
  - Regional frequency and severity in many cases
- Quantification of the economic impact of each characteristic scenario on a typical city
  - Incorporating physical vulnerability and social and economic resilience of the city
  - Output in terms of 'GDP@Risk' –a standard metric to compare different threats
- Threat Map Data Visualisation

Selecting the Representative Cities



We picked the 'A List' of the world's cities for this analysis:

- Economically most important cities of 50 largest economies
  - Top 25 cities in US (#1 economy) and top 32 cities in China (#2 economy)
  - Between 5 – 12 largest cities for rest of the top 17 economies
- Include all cities over 3m population in the world
- Consist half of the world's capital cities
- Responsible for **half** of the World's GDP today
- Contribute **two-thirds** of the World's GDP in **2025**

A Systematic Review of Cities at Risk

- Economic impacts of the ***city-level GDP***
- In order of priority, the following resources were used to build the CityGDP database
  1. OECD
  2. Country own database estimates
  3. Brooking Institute
  4. McKinsey Global Institute (*Urban World: Mapping the Economic Power of Cities*, 2011)
  5. PwC (*Cities of Opportunities 6*, 2014)
  6. Other online sources

A Systematic Review of Cities at Risk *(cont.)*

- Building the database for city-level GDP and population estimates:

Source types	Primary	Secondary	Tertiary
Resources	▪ OECD ▪ Countries' own city estimates (Official records)	▪ Brooking Institute ▪ McKinsey Global Institute ▪ PwC	▪ Other online sources (E.g. Wikipedia)
Cities	2/3 matched with overlapping data		Remaining

- Validation (Sense Checking)
  - GDP(Country) per capita $\leq$ GDP(City) per capita

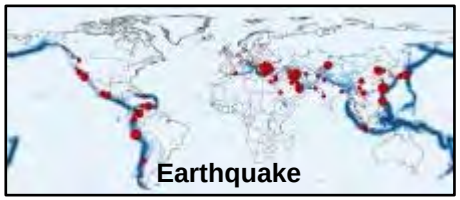
Overview of Threat Models

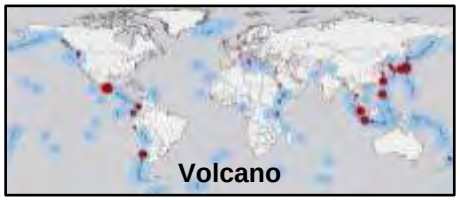
ID		Threat	Phase	Hazard Map	Severity Scale	Cause	Projection	Uncertainty
Natural Catastrophe & Climate								
1.1	EQ	**Earthquake**	1	United States Geological Survey; GSHAP	Ms (Surface-wave Magnitude)	Natural	Constant	Low
1.2	VE	**Volcanic Eruption**	1	Smithsonian Institute of Volcanology	VEI (Volcanic Explosiivity Index)	Natural	Constant	Medium
1.3	HU	**Tropical Windstorm**	2	EM-DAT; Pacific Research Center; Munich Re	Saffir-Simpson CAT Hurricane Scale	Natural	CC Trend	Low
1.4	WS	**Temperate Windstorm**	2	EM-DAT Windstorm Database	Beaufort Wind Scale	Natural	CC Trend	Low
1.5	FL	**Flood**	1&2	UNEP/DEWA/GRID-Europe Flood Risk Rating	Depth and velocity of flood water	Natural	CC Trend	Low
1.7	TS	**Tsunami**	2	NOAA NCDC Historical Tsunami Database	Run-up height	Natural	CC Trend	Medium
1.8	DR	**Drought**	2	US National Center for Atmospheric Research	Palmer Drought Severity Scale	Natural	CC Trend	Medium
1.10	FR	**Freeze**	2	Global Climate Zoning Map	Degree-Days below 0C	Natural	CC Trend	Medium
1.11	HW	**Heatwave**	2	Global Climate Zoning Map	Degree-Days Above 32C	Natural	CC Trend	Medium
Financial, Trade & Business								
2.1	MC	**Market Crash**	1	IMF Banking Network Core-Periphery Designation	S&P500 Index reduction	Man-Made	Dynamic	High
2.2	SD	**Sovereign Default**	1	S&P National Credit Ratings	% Devaluation of national currency	Man-Made	Dynamic	Medium
2.3	OP	**Oil Price Shock**	2	UN imported oil intensity of GDP output	% increase in oil price (Brent Crude)	Man-Made	Dynamic	Medium
Technology & Space								
4.1	PO	**Power Outage**	2	Nation Master Electrical Outage Report	City-Days of Outage	Man-Made	Constant	Medium
4.2	CY	**Cyber Catastrophe**	1	McAfee International Cyber Risk Report	Cyber Magnitude & Revenue@Risk	Man-Made	Dynamic	High
4.3	SS	**Solar Storm**	2	US National Oceanic and Atmospheric Administration	US NOAA Space Weather Scale	Natural	Constant	High
4.4	NP	**Nuclear Meltdown**	2	World Nuclear Association Information Library	Intntl Nuclear Events Scale (INES)	Man-Made	Constant	Low
Health & Environmental								
5.1	HE	**Human Epidemic**	1	Emerging Infectious Diseases, Institute of Zoology	US CDC Pandemic Severity Index	Natural	Dynamic	Medium
5.2	PE	**Plant Epidemic**	2	Wallingford Distribution Maps of Plant Diseases	Staple Crop (Wheat) Price Index	Natural	Dynamic	Medium

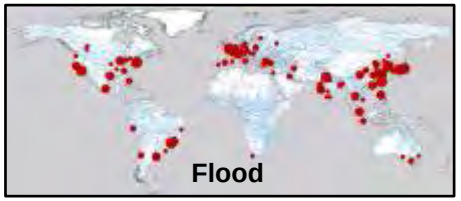
Mapping Threat Models to Cities

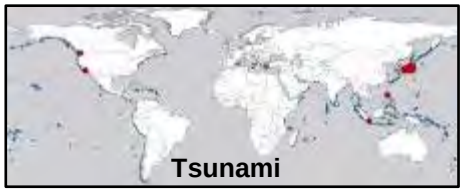
City Name	Delhi	Istanbul	Los Angeles
Country	India	Turkey	United States
CRS Index	IND_DEL	TUR_IST	USA_CAL
GDP 2014	**246.6**	**343.6**	**774.8**
GDP 2025	**578.0**	**679.4**	**880.7**
Economic Resilience	**5** Very Weak	**3** Moderate	**1** Very Strong
Economic Sectoral Type	**C** Service with Industry	**C** Service with Industry	**A** Service-Dominated Economy
Physical Vulnerability	**4** Weak	**3** Moderate	**1** Very Strong
Flood Vulnerability	**4** Economy Highly Vulnerable to Flood Disruption	**4** Economy Highly Vulnerable to Flood Disruption	**5** Economy Very Highly Vulnerable to Flood Disruption
Financial Vulnerability	**3** Moderate Reliance on Private Capital	**2** Low Reliance on Private Capital	**5** High Reliance on Private Capital
Cyber Vulnerability	**4** High Vulnerability to Cyber Attack	**4** High Vulnerability to Cyber Attack	**5** Very High Vulnerability to Cyber Attack
Pandemic Vulnerability	**3** Moderate Healthcare System	**3** Moderate Healthcare System	**1** Very Strong Healthcare System
Earthquake Threat	**D** Some Hazard	**B** High Hazard	**A** Very High Hazard
Volcano Threat	**F** No recent volcanic activity in region	**F** No recent volcanic activity in region	**F** No recent volcanic activity in region
Flood Threat	**A** High Threat from Flood	**F** No Information on Flood	**B** Moderately High Threat of Flood
Market Crash Threat	**C** Integral part of International Financial System	**B** Local Markets Volatile	**C** Integral part of International Financial System
Sovereign Default Threat	**C** Moderate Chance of Sovereign Default	**B** Significant Chance of Sovereign Default	**D** Low Chance of Sovereign Default
Cyber Threat	**A** High Cyber Threat	**B** Moderate Cyber Threat	**A** High Cyber Threat
Pandemic Threat	**A** High Threat of Emerging Infectious Diseases	**B** Moderately High Threat of Emerging Infectious Diseases	**C** Possible Threat of Emerging Infectious Diseases

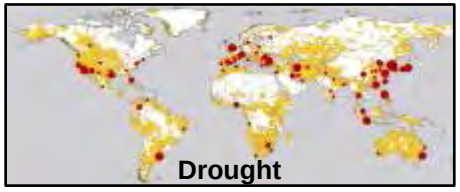
Geographical Mapping the Threats

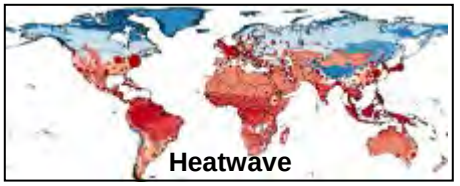


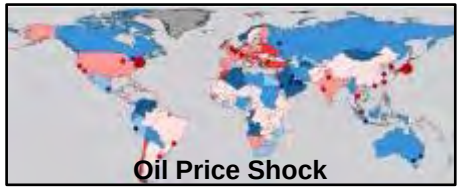


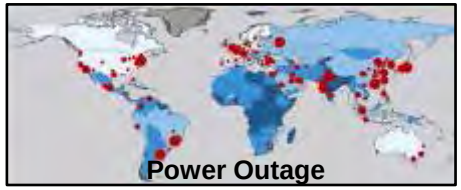


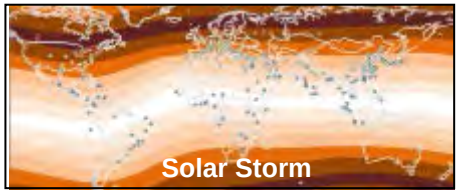


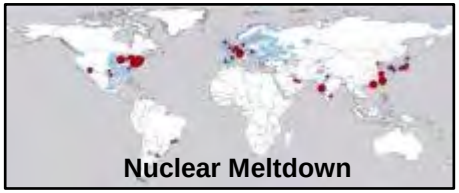






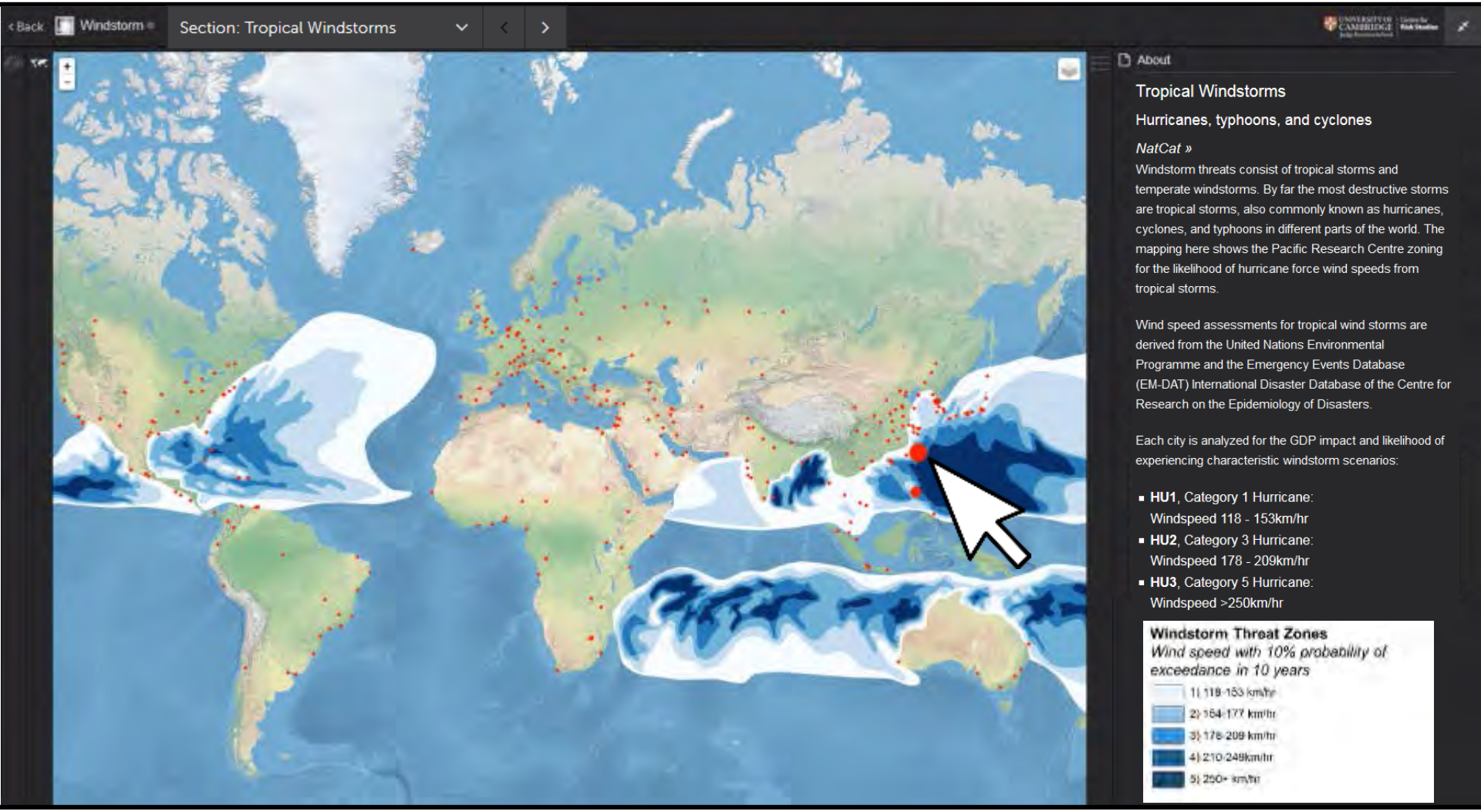




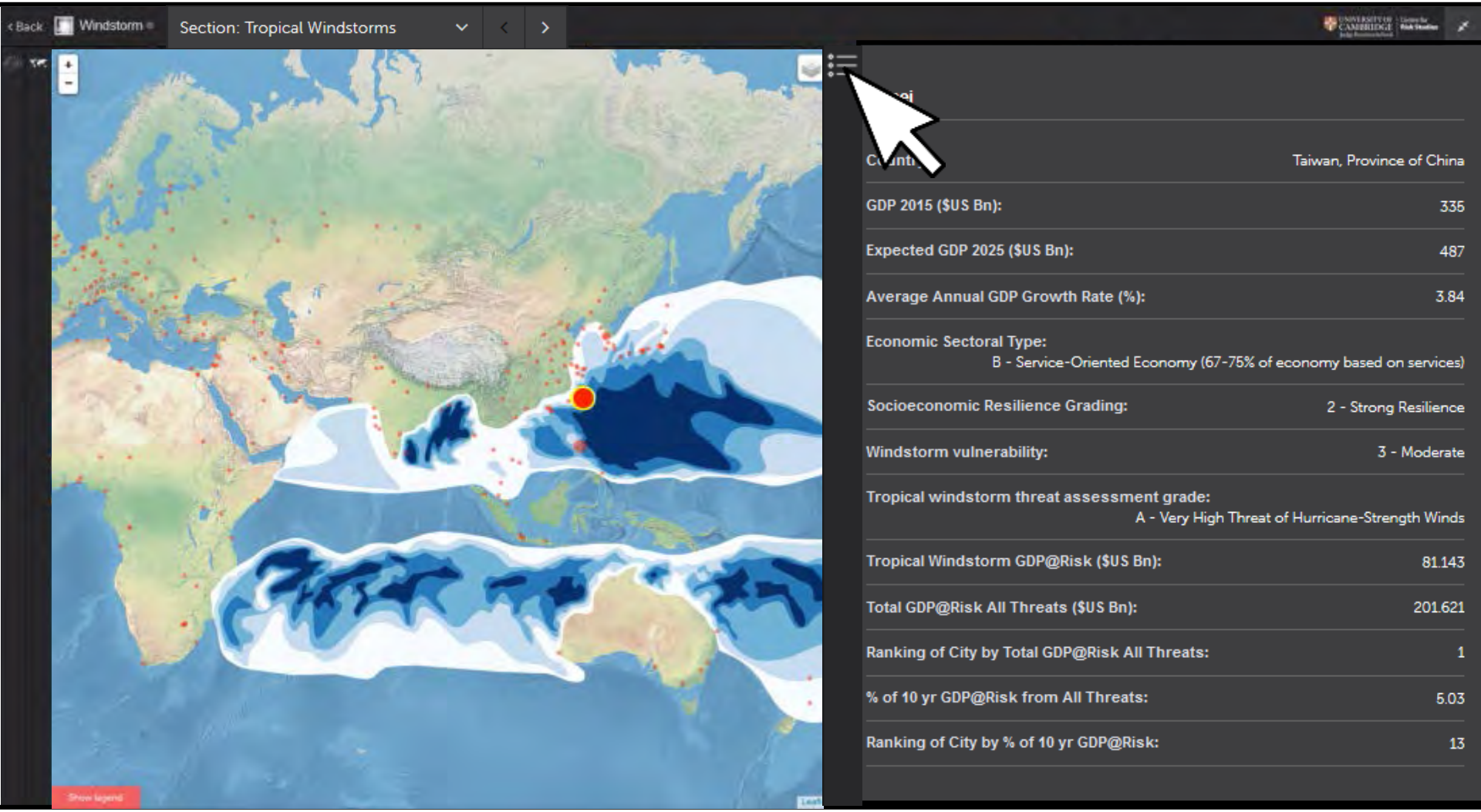


Cambridge World City Risk Atlas

World City Risk:
Interactive Maps - Windstorms



Tropical Windstorm



World City Risk:
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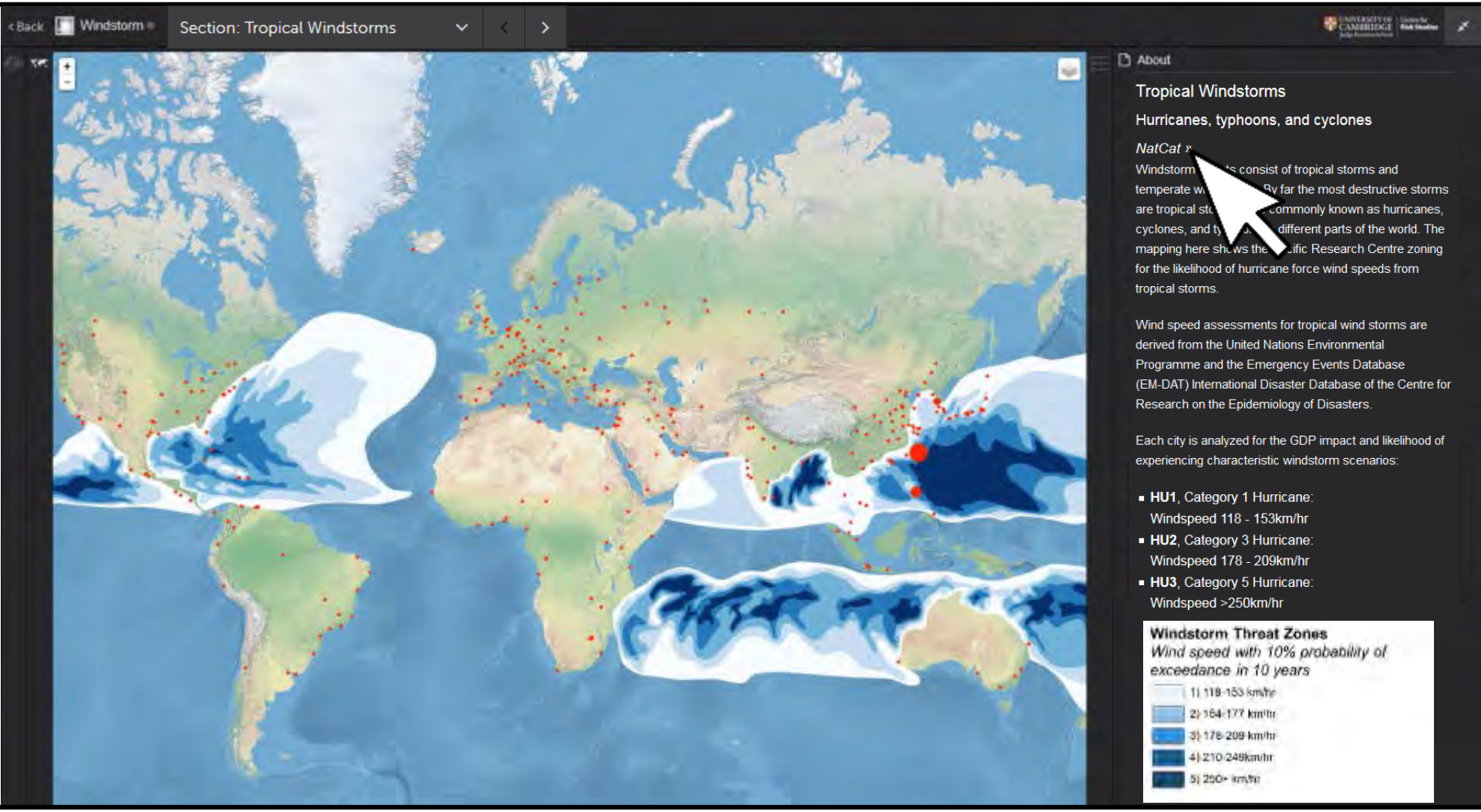

Cambridge Threat Observatory

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5 NATURAL CATASTROPHE

Naturally occurring phenomena causing widespread disruption

Threat Class	Description
 5.1 **Earthquake**	Seismic fault rupture causes high levels of damage to infrastructure of a major populated area
 5.2 **Windstorm**	Hurricane/typhoon/cyclone wind system makes landfall onto a major populated area; European-type windstorm system, large scale, fast-moving, gale force wind speeds
 5.3 **Tsunami**	Coastal impact of a tidal wave, caused by offshore earthquake, marine landslide, or meteorite in the sea
 5.4 **Flood**	River Flood from high rainfall/sudden water release across one or more river systems; Coastal Flood from sea surge caused by low pressure weather systems, exceptional tides and extreme winds
 5.5 **Volcanic Eruption**	Ash, pyroclastic hot gasses, lava, and lahar-triggered mudflows cause localized destruction and regional disruption

NatCat news watch

Typhoon gives Taiwan a gigantic
The Guardian - **Sep 30, 2015**
Taiwan faces a big clear-up after **Typhoon** Dujuan, which killed at least two people, injured more than 300, displaced thousands and left nearly half a million without power. On Monday

Typhoon Dujuan Kills 3, Batters
NASA's GPM analyzes Typhoon
EurekAlert (press release) - AsiaOne - WantChinaTimes
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Pacific Tsunami Warning Center *US National Oceanic and Atmospheric Adminstration (NOAA)*
Global Volcanism Program *Smithsonian / United States Geological Survey*
Worldwide Flood Forecasting *Regional Integrated Multi-Hazard Early Warning System (RIMES)*
European Floods Portal *European Commission Joint Research Centre*
European Severe Weather Database *ESWD*
RMS Cat Updates *Risk Management Solutions*
Tropical Cyclones *Earth Observation Research Center, Japan Aerospace Exploration Agency*

Risk Briefing – Lloyd's City Risk Index 2015-2025

6 October 2015

Catastronomics and World City Risk

Centre for Risk Studies

UNIVERSITY OF CAMBRIDGE
Judge Business School

Dr Scott Kelly
Cambridge Centre for Risk Studies

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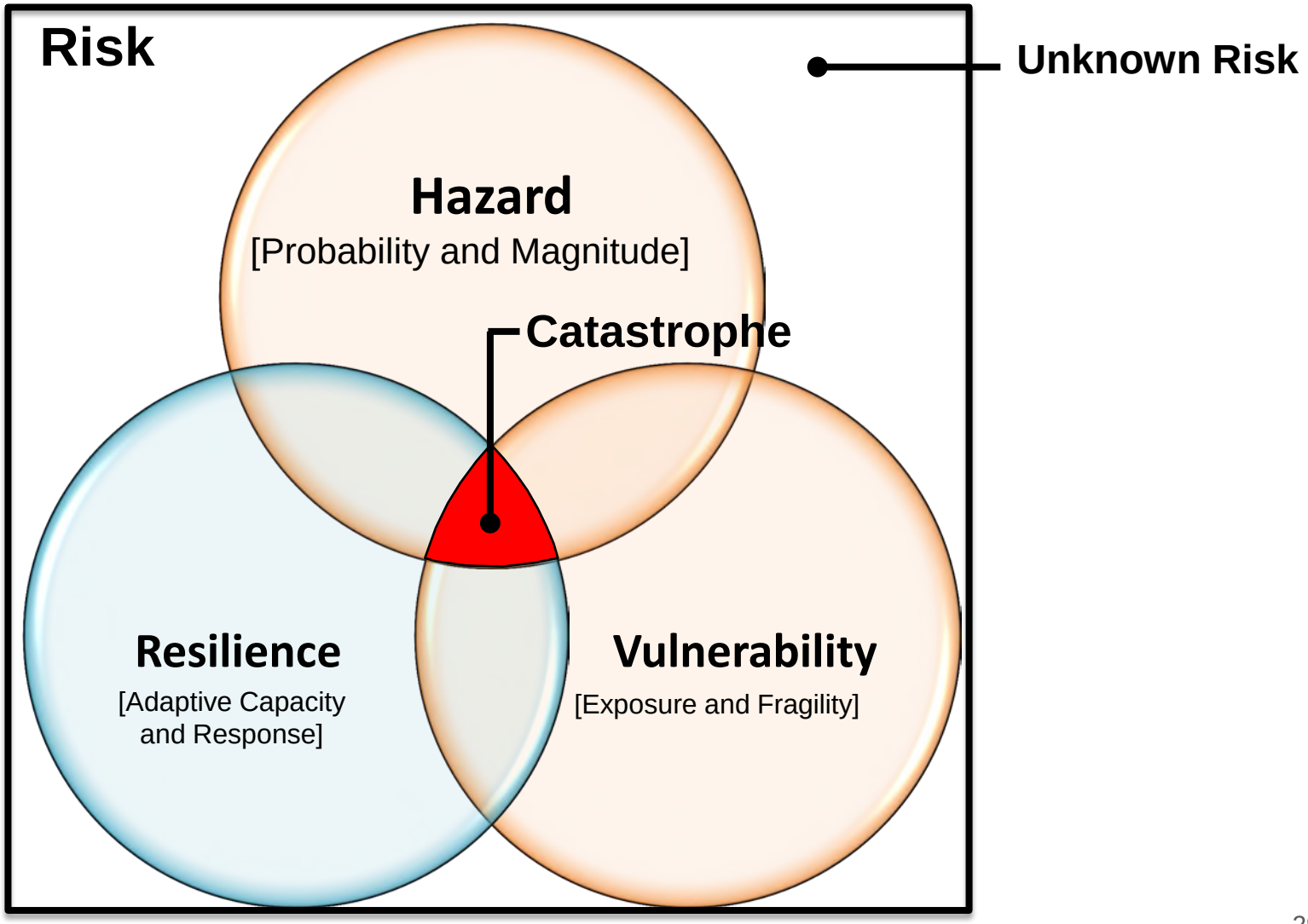
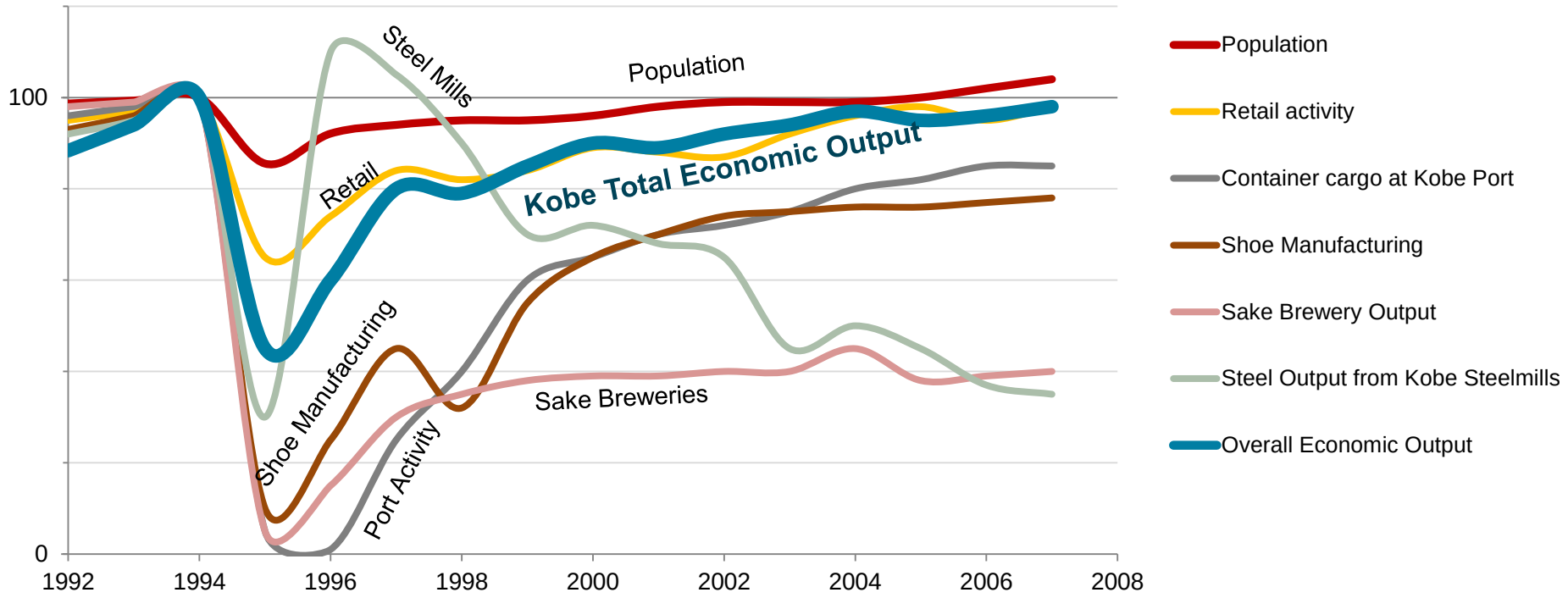
Catastronomics

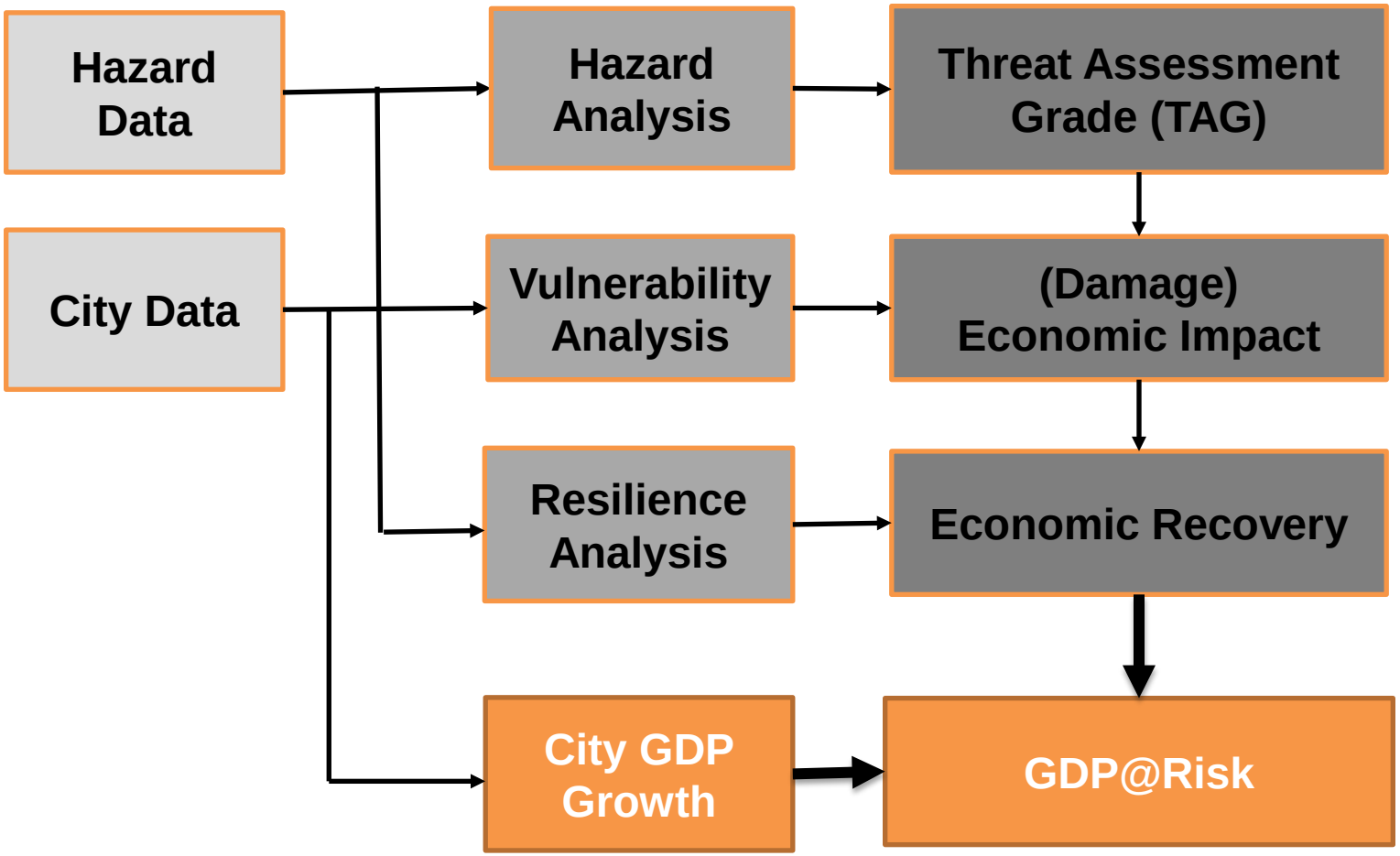


Impact of 1995 Earthquake on Economy of Kobe, Japan

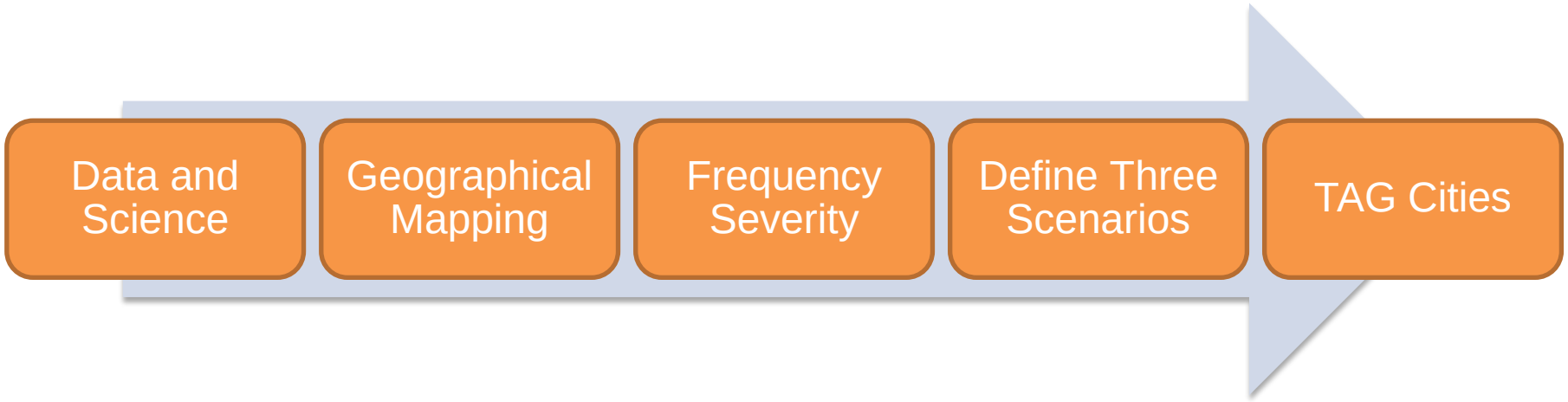


- Great Hanshin earthquake January 17, 1995, Magnitude 7.3
- Death toll 6,400; Direct damage costs $100 billion
- The port of Kobe, one of the world's busiest, was destroyed
- Kobe Steel Ltd, major steel maker, heavily damaged
- 80% of shoe factories damaged
- 50% of the region's sake breweries put out of action
- Kobe's economic output halved in 1995, reducing Japan's total industrial output by 2.6 percent

GDP@Risk Estimation Process

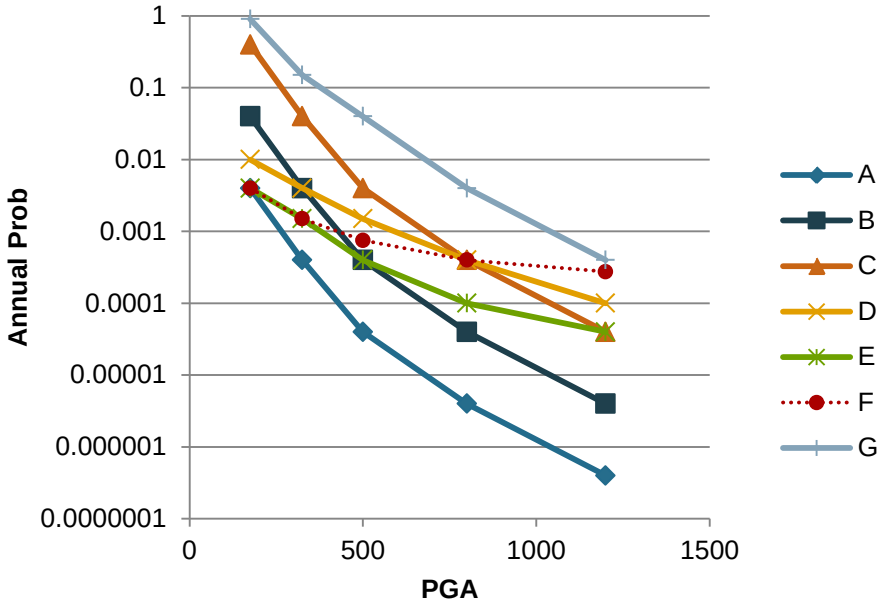


Hazard Analysis - TAGs



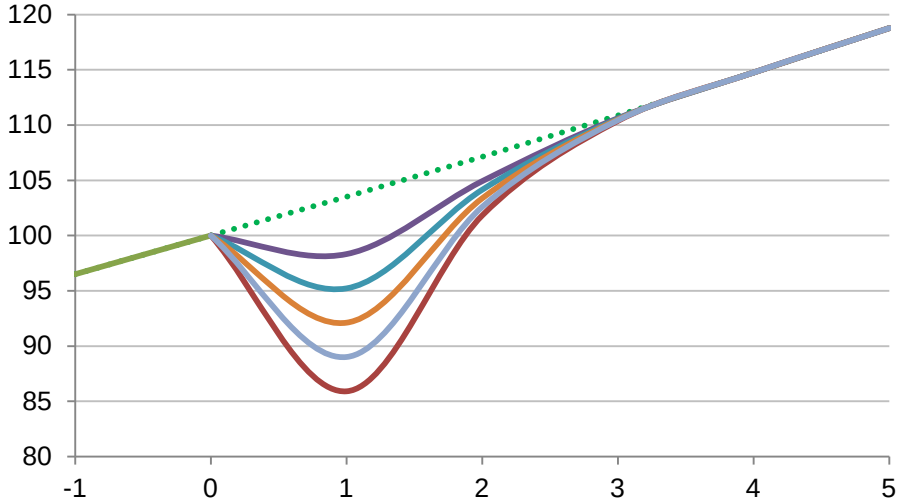
Quake Map Banding of City					PGA 2500		
					250-400	400-600	600-1000
					VII	VIII	XI
PGA 250					0.0004	0.0004	0.0004
	MidRange	MMI equiv	Annual Frequency				
100-250	175	VI	0.004		**A**	**E**	**F**
250-400	325	VII	0.004			**B**	**D**
400-600	500	VIII	0.004				**C**
600-1000	800	XI	0.004				**G**

		Annual Probs						
	PGA	A	B	C	D	E	F	G
VI	175	0.004	0.04	0.4	0.01	0.004	0.004	0.9
VII	325	0.0004	0.004	0.04	0.004	0.0015	0.0015	0.15
VIII	500	0.00004	0.0004	0.004	0.0015	0.0004	0.00075	0.04
XI	800	0.000004	0.00004	0.0004	0.0004	0.0001	0.0004	0.004
XI	1200	0.0000004	0.000004	0.00004	0.0001	0.00004	0.000275	0.0004



City Vulnerability Analysis

	Small	Medium	Large
1 Very Strong	97.0%	95.0%	80.0%
2 Strong	95.0%	85.0%	70.0%
3 Moderate	90.0%	75.0%	60.0%
4 Weak	80.0%	68.0%	50.0%
5 Very Weak	75.0%	50.0%	40.0%

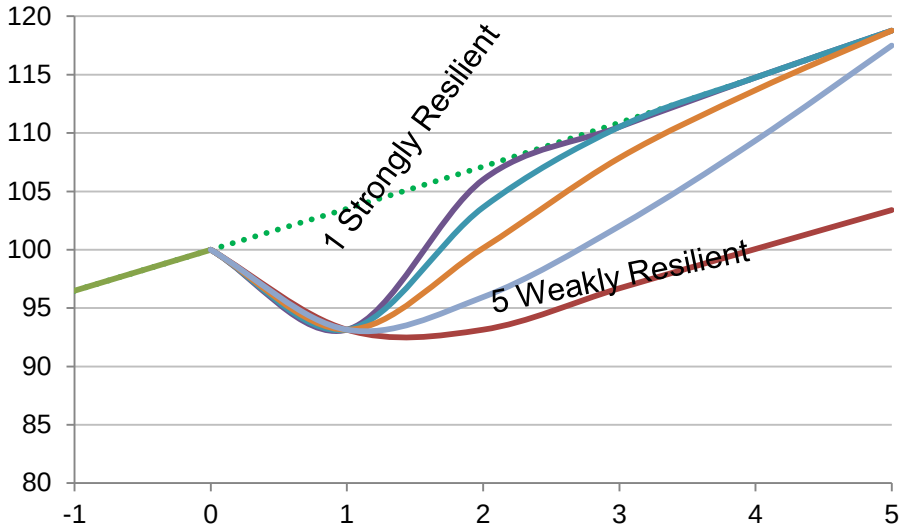


- **Physical vulnerability** includes assessment of the quality of buildings and compliance to construction codes.
- **Flood vulnerability** considers water damage loss by economic sector
- **Cyber vulnerability** considers the reliance on IT and its criticality for the city's economic output
- **Financial vulnerability** considers connectivity and impact from a financial crisis
- **Pandemic vulnerability** includes healthcare index assessment by World Health Organization

City Resilience Analysis

Recovery Period

	Small	Medium	Large
1 Very Strong	3	3	3
2 Strong	3	3	3
3 Moderate	3	4	6
4 Weak	4	4	7
5 Very Weak	4	5	8



- The speed of recovery of the city is influenced by its social and economic resilience, and physical capacity to respond
- We have developed a resilience classification (1-5) for cities based on four factors
  - Governance; Social coherence; Economic strength; Infrastructure systems
- Recovery is calibrated from precedent studies of economic recovery after disaster

Analysis of Economic Loss in a Catastrophe

Supply Shock

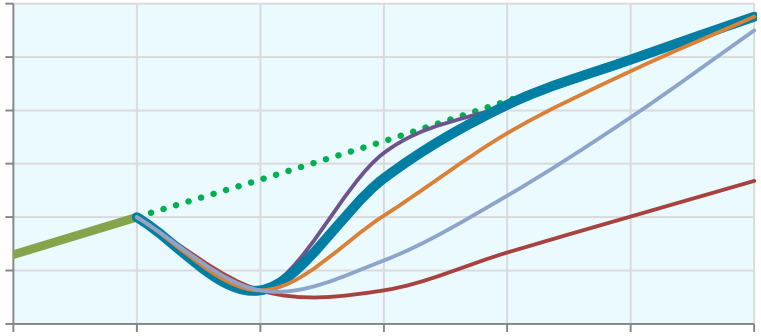
Destruction of Physical Assets

Disruption of Labour Availability

Flight of Capital

Inability to Export

Government Recovery Stimulus



Catastronomics Model

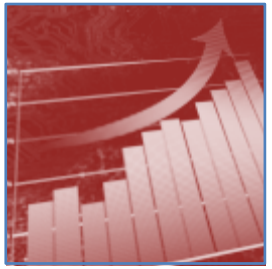
Demand Shock

Consumer Confidence

Shortage of Private Capital

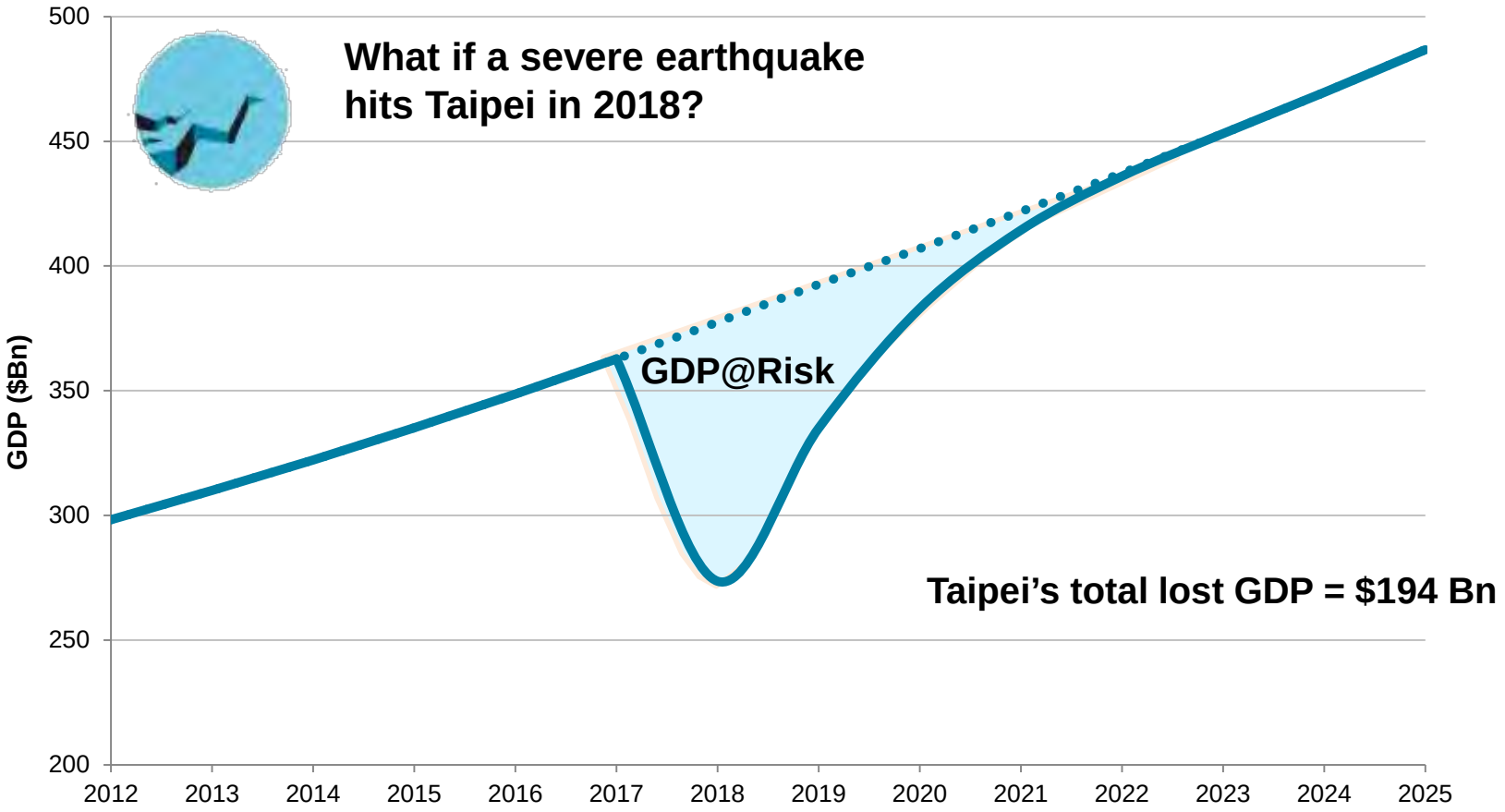
Share Price Reduction

Inability to Import



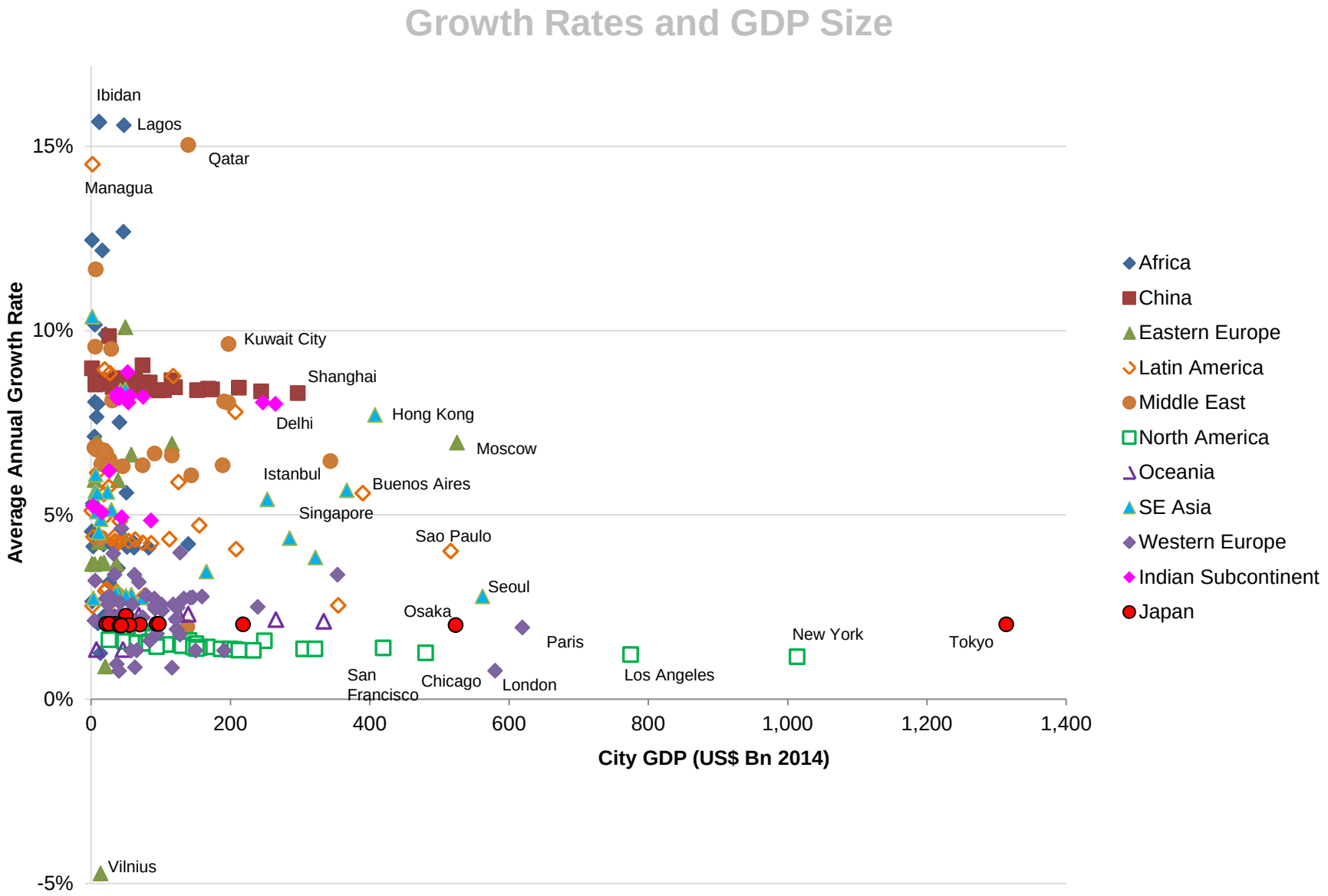
Inflation: increased cost of inputs

GDP@Risk

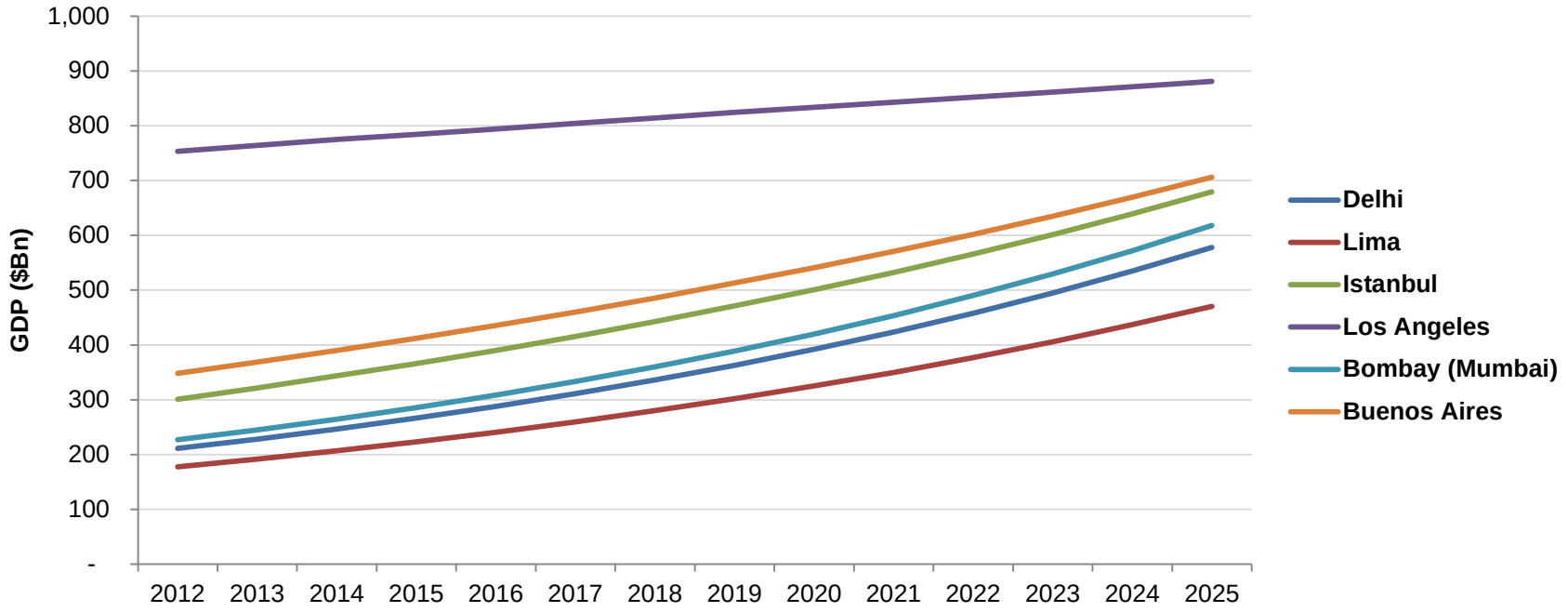


- Taipei has a Threat Assessment Grading for earthquake of 'Very high threat' based on United States Geological Survey earthquake design code assessment of Taipei
- An earthquake that would affect the city centre with shaking of PGA 400-600 cm/s2 (MMI VIII) could be expected approximately once every 133 years (annual probability of 0.0075)

Cities, GDP and Projected Growth Rates



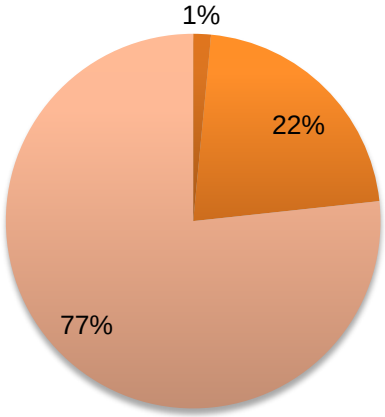
GDP Projections



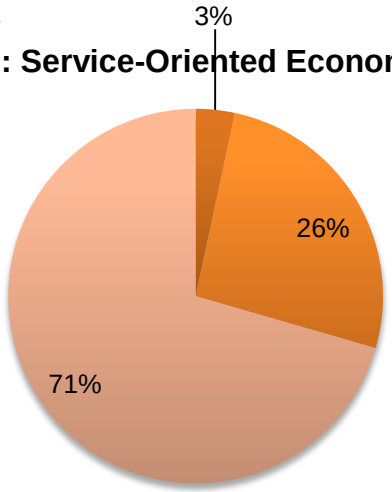
- GDP projections for each year to 2025 have been derived for each of the 300 cities
- These draw on studies from McKinsey, Brookings Institute, and macroeconomic projections by country from Oxford Economics
- Projections take account of trends in GDP per capita, future demographic change, capital investment, and sectoral economic outputs

Economy Mix: Classification of Cities

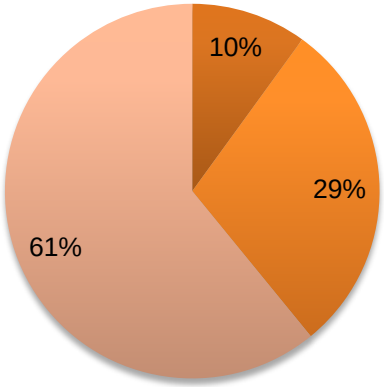
A: Service-Dominated Economy



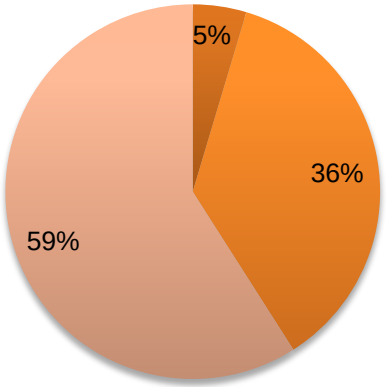
B: Service-Oriented Economy



C: Service with Industrial

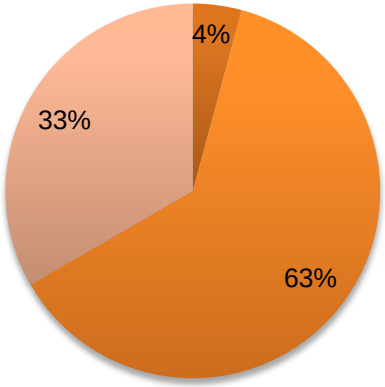


D: Service-Industrial

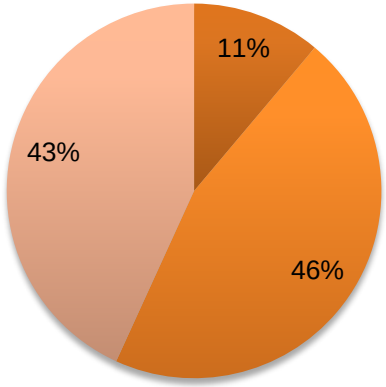


Average mix within cities classified in that category

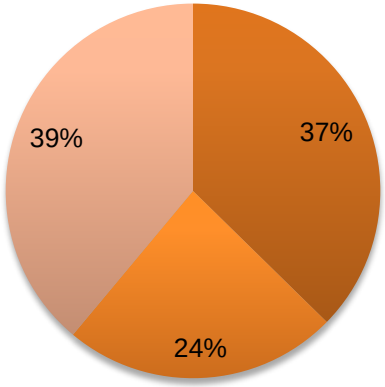
E: Industrial-Oriented Economy



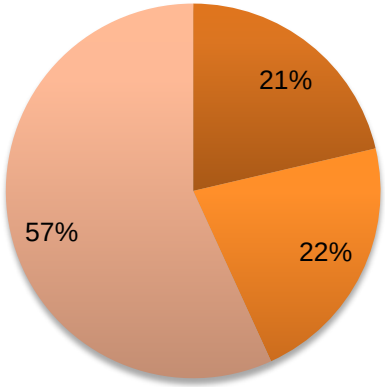
F: Industrial with Service



G: Agriculture with Ind & Service



H: Service with Industria/Ag Mix



Vulnerability (Physical Destruction Threats)

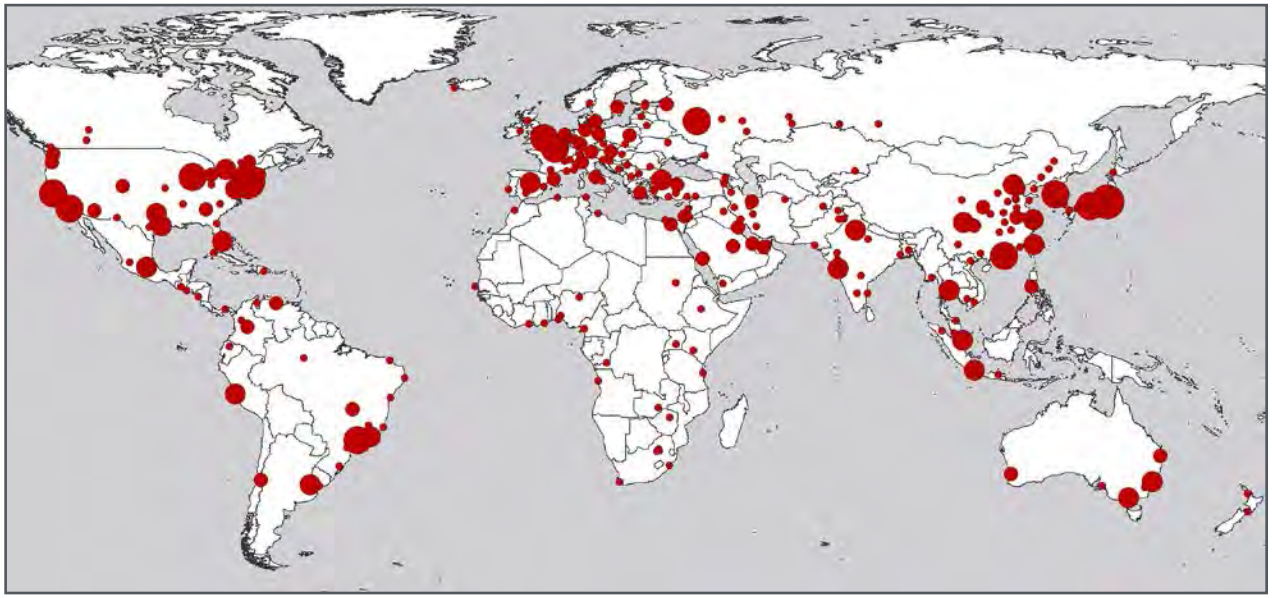
Resilience	Example cities
1 – Very Strong	San Diego, Tokyo, Wellington, Helsinki, Singapore, Santiago
2 – Strong	Berlin, Paris, Leeds, Rome, Montreal, Adelaide, Madrid, Amsterdam
3 – Moderate	Beijing, Sao Paulo, Seol, Ankara, Izmir, Warsaw, Buenos Aires
4 – Weak	Moscow, Delhi, Cape Town, Durban, Bangkok, Lahore, Ho Chi Minh
5 – Very weak	Douala, Abidjan, Accra, Pyongyang, Dakar, Lusaka, Harare

Resilience (All Threats)

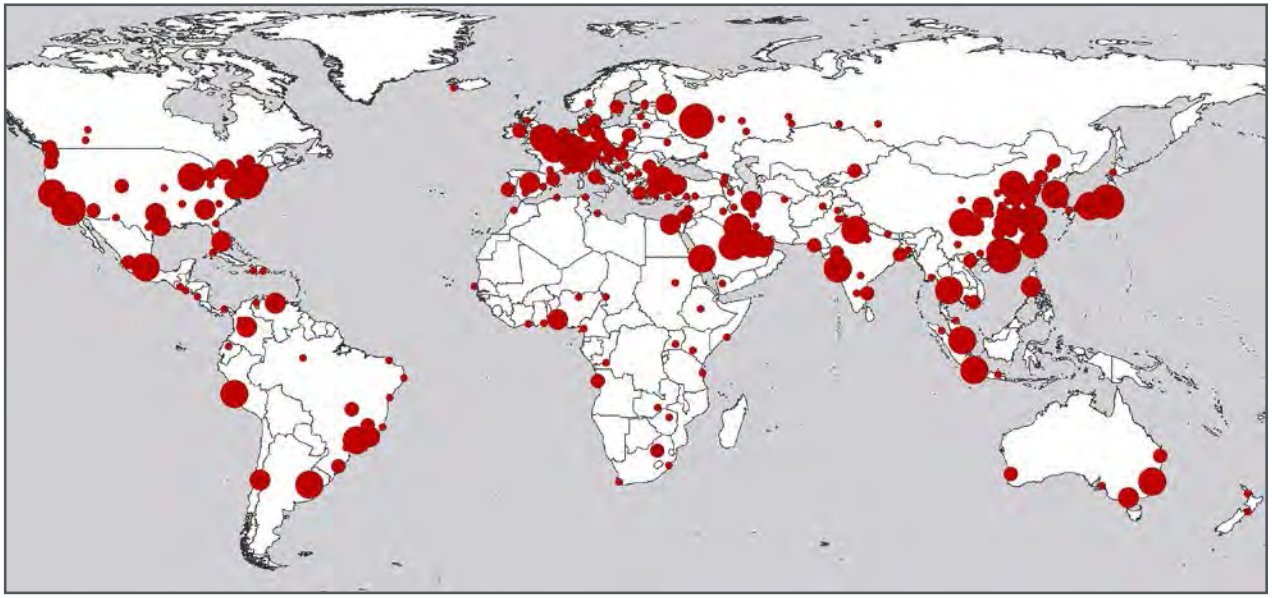
Resilience	Example countries
1 – Very Strong	New Zealand, Singapore, Japan, Germany, United Kingdom
2 – Strong	Chile, Kuwait, Israel, United Arab Emirates, Taiwan
3 – Moderate	Greece, Hungary, Czech Republic, Georgia, Brazil
4 – Weak	Armenia, Morocco, Philippines, Argentina, Guatemala
5 – Very weak	Kenya, Tanzania, Ethiopia, Cote d'Ivoire, Myanmar

GDP 2015-2025

2015



2025



City GDP ($US Bn)

- 2 - 100
- 101 - 200
- 201 - 400
- 401 - 800
- 800 - 1635

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Multi Threat Project ⇨ Where Next?

- World Cities at Risk essentially adds up impacts across 20-some threat types and 300 cities
  - Events and cities are treated as independent
  - ⇨ **Introduce interdependence**
- What is the arithmetic of catastrophe?
  - Does a combined 1-in-50 year Hurricane and 1-in-50 year Sovereign Default cause more havoc than a 1-in-100 year event?
  - ⇨ **Nonlinearity of combined effects**
  - Can a War cause a Pandemic resulting in far greater mortality than either event on their own?
  - ⇨ **Cascading risks**

Risk Briefing – Lloyd's City Risk Index 2015-2025

6 October 2015

Model Results and Next Steps

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Louise Pryor

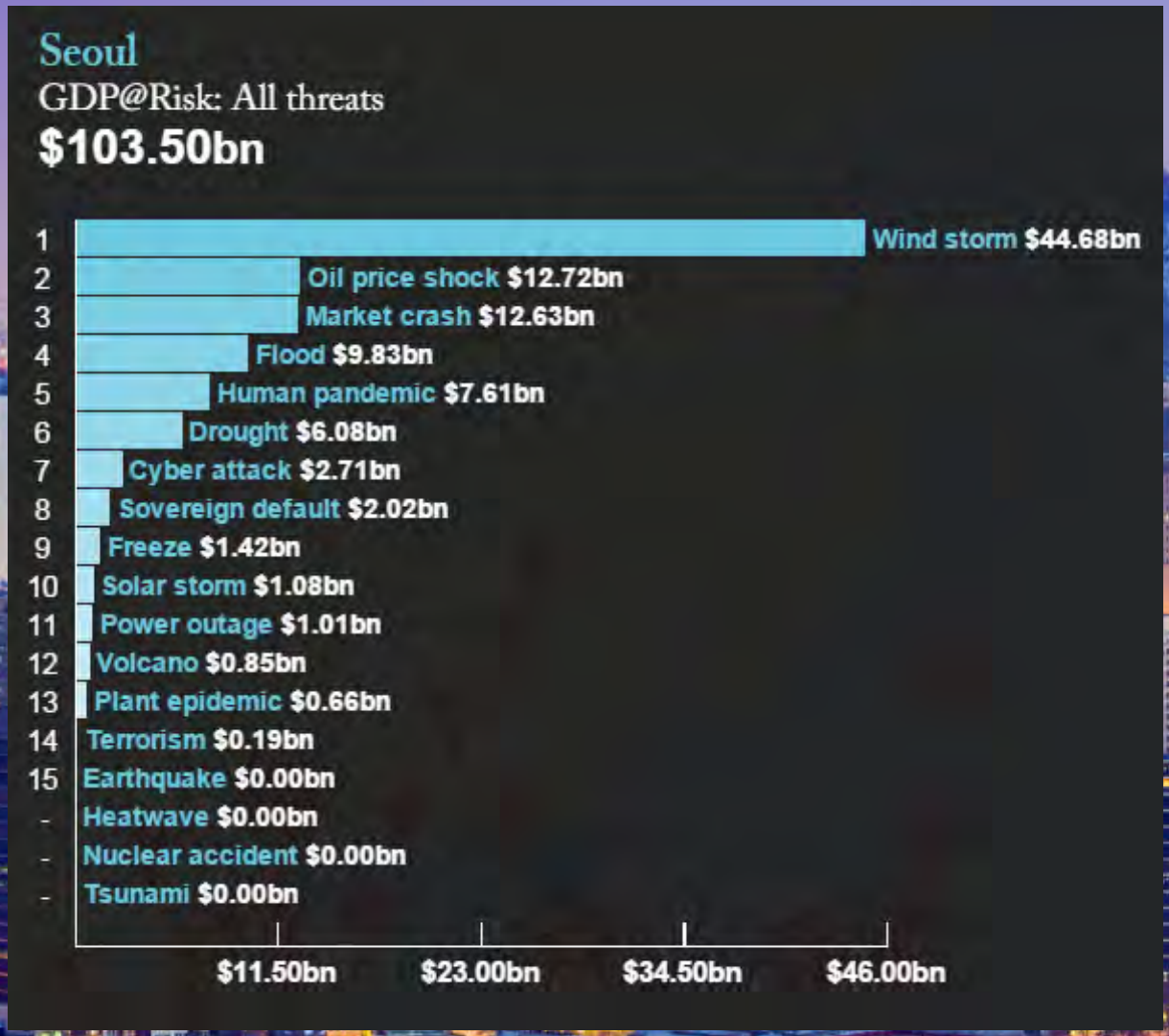
Cambridge Centre for Risk Studies

LLOYD'S

Agenda

- Model results
- They are reasonable
- … but more could be done

GDP@Risk metrics for a city – a risk profile



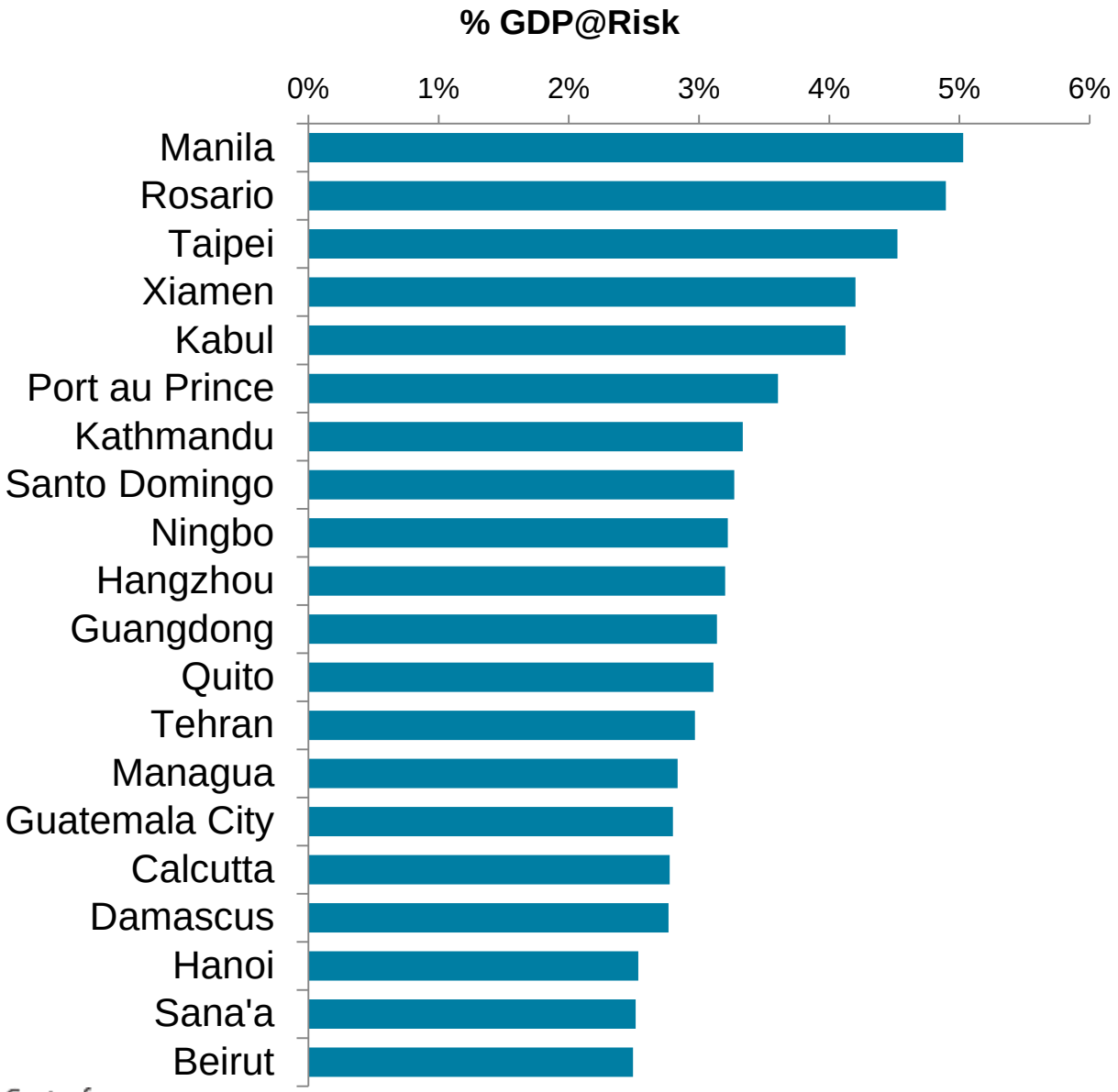
City totals


Select threat
All threats
All threats
GDP@Risk: All cities
$4.56trn
GDP@Risk: Top 20 cities
$1.61trn
35.20% of All cities total
GDP@Risk: Top 5 cities
1 Taipei $181.20bn
2 Tokyo $153.28bn
3 Seoul $103.50bn
4 Manila $101.09bn
5 New York $90.36bn
View top 20
View case studies
Share this data

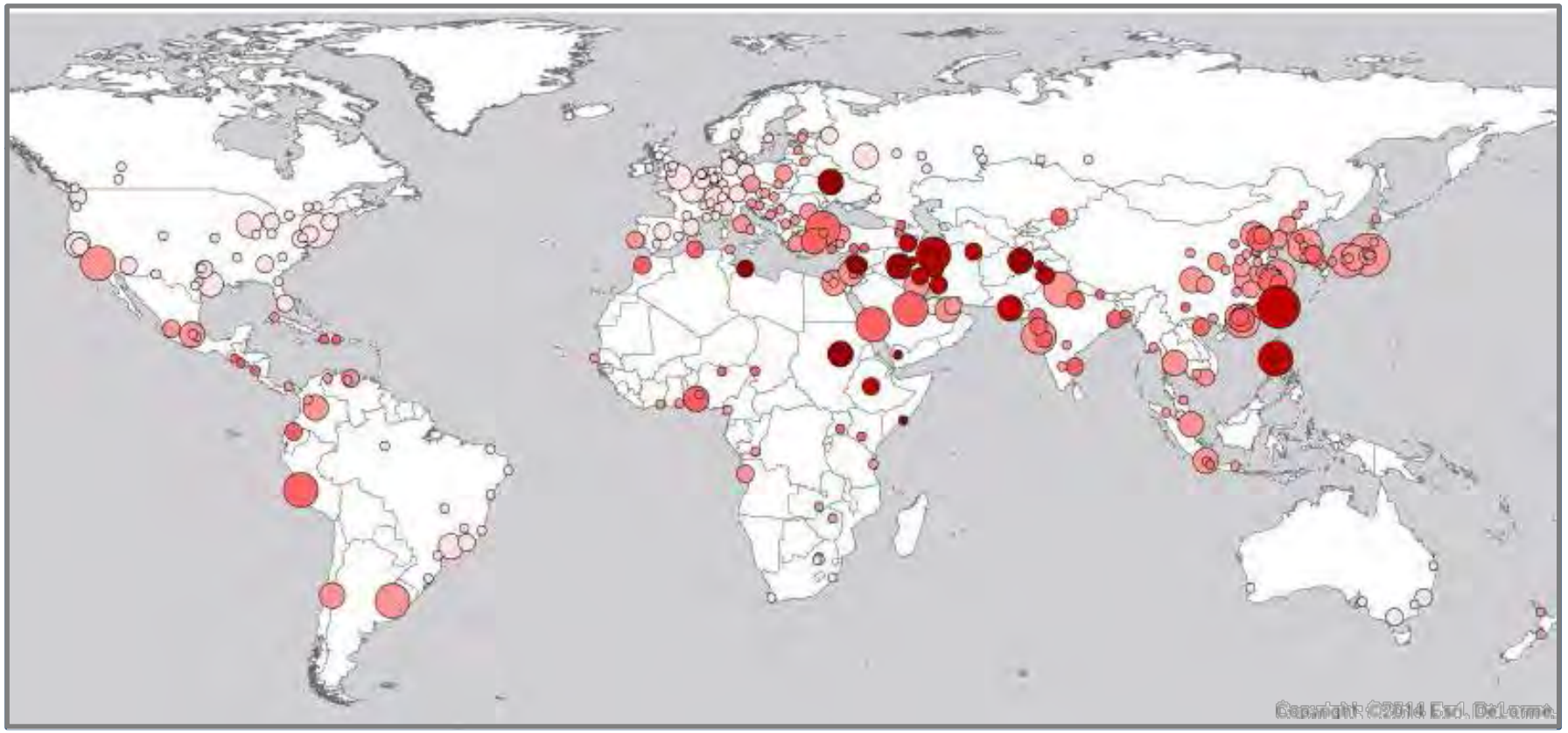

GDP@Risk: Top 20 cities
All threats
1 Taipei $181.20bn
2 Tokyo $153.28bn
3 Seoul $103.50bn
4 Manila $101.09bn
5 New York $90.36bn
6 Los Angeles $90.32bn
7 Istanbul $82.50bn
8 Osaka $79.32bn
9 Shanghai $78.21bn
10 Hong Kong $74.51bn
11 Lima $69.36bn
12 Tehran $64.14bn
13 Sao Paulo $62.95bn
14 Mexico City $60.74bn
15 Moscow $55.77bn
16 Paris $54.94bn
17 London $53.43bn
18 Singapore $51.11bn
19 Buenos Aires $50.31bn
20 Jakarta $48.23bn


GDP@Risk: Top 20 cities
Natural threats
1 Taipei $137.69bn
2 Tokyo $99.38bn
3 Manila $91.68bn
4 Seoul $72.22bn
5 Shanghai $58.06bn
6 Osaka $52.72bn
7 Hong Kong $48.39bn
8 Istanbul $48.13bn
9 Mexico City $47.94bn
10 Lima $46.73bn
11 Los Angeles $46.45bn
12 Tehran $44.73bn
13 Hangzhou $37.63bn
14 Tianjin $34.70bn
15 Dongguan $33.59bn
16 Guangzhou $31.86bn
17 New York $31.19bn
18 Shenzhen $30.36bn
19 Beijing $29.87bn
20 Jakarta $27.58bn

Risk as a % of GDP



GDP@Risk


Cities - GDP at Risk - Total US$ (Bn)
0.0 - 12.0
12.1 - 30.0
30.1 - 65.0
65.1 - 115.0
115.1 - 217.0
Cities - GDP at Risk - Total %
0 - 1
1 - 2
2 - 3
3 - 6
6 - 12

If Manila improved its ‘resilience’ and ‘economic vulnerability”

	Total $GDP@Risk (Bn)	World Ranking by $GDP@Risk	as % of total GDP 2015-2025	World Ranking by % of GDP
Resilience 'Weak'	$101	4	5.0%	1
Resilience 'Moderate'	$89	6	4.4%	2
Resilience 'Very Strong'	$70	10	3.5%	5
Resilience and economic vulnerability up one grade	$58	13	2.9%	13
Same level as Los Angeles	$27	42	1.3%	101

Comparison with History

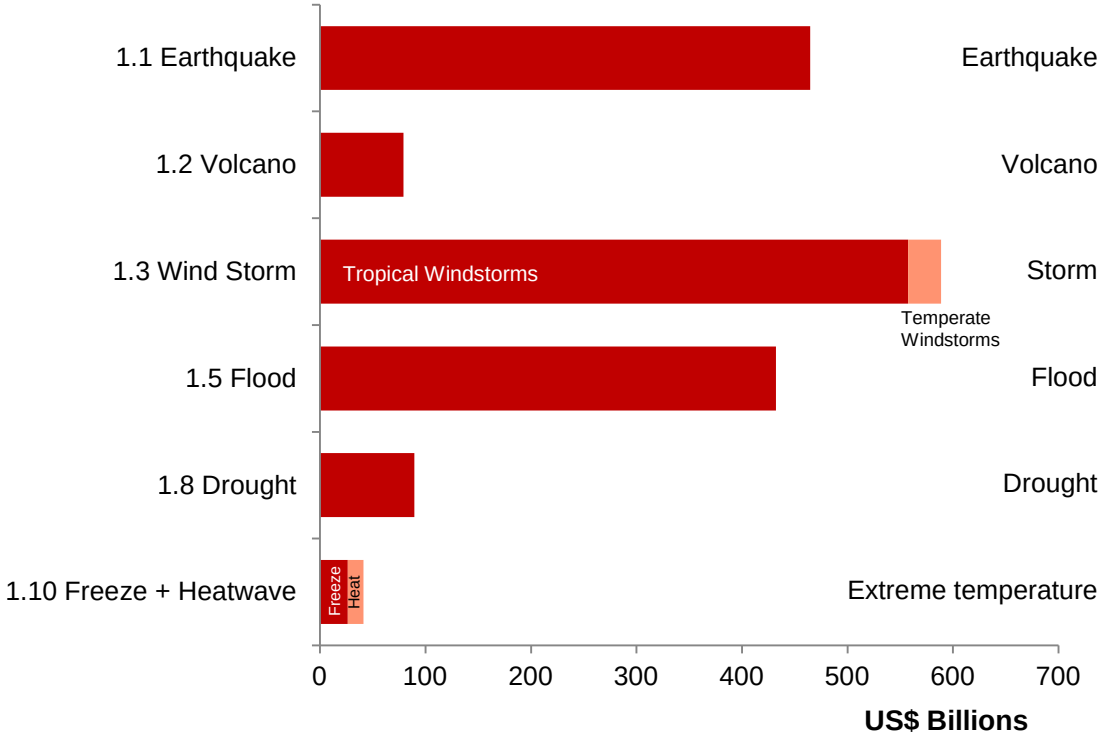
Expected Loss of Economic Output

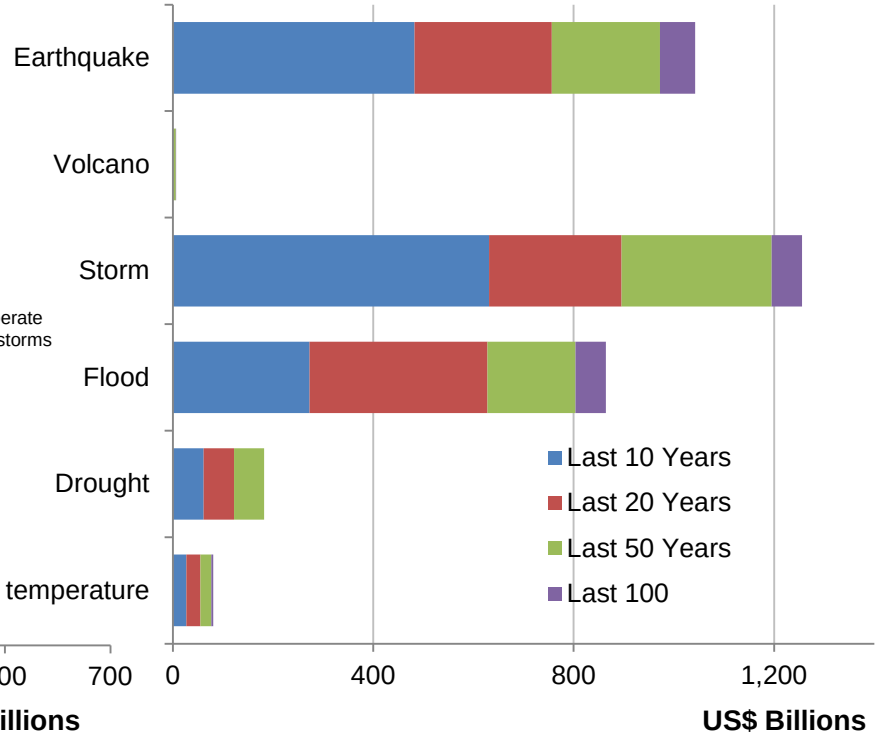
- Modelled over next 10 years
- 300 cities
- Economic output

Historical Data Direct Costs of Natural Catastrophe

- Observed Past 100 years
- Worldwide
- Repair costs to physical infrastructure

EM-DAT Database of CRED
3,806 events since 1900





Comparisons with other models

- US National Bureau of Economic Research compared GPD erosion from cyclones with estimates of other threats

US NBER	National GDP Impact
Cyclone	1.00
Civil War	0.86
Currency Crisis	1.11
Banking Crisis	2.08

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

- Swiss Re's CatNet – data on natural hazards and cities

Doing more and better

- More cities, more threats
- More detail
- Interactions and connections
- More use cases
- Better metrics

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