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Climate change: A risk to the global middle class

Exposure, vulnerability & economic impact

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Climate change: A risk to the global middle class

Natural hazards are ever present in our lives. However, hazards such as temperature and weather extremes can turn into natural disasters if there are people exposed to the hazard who are not resilient enough to fully absorb the impact without suffering damage to life or property.

Adapted from Anna K. Schwab, Katherine Eschelbach, and David J. Brower. 2007. Hazard Mitigation and Preparedness. Hoboken, N.J.: John Wiley and Sons.

Executive summary

In the first six months of 2015, natural catastrophes caused 16,200 fatalities and total economic losses of USD 32 billion (measured at 2014 values), of which USD 12 billion were insured. Winter storms in the United States, Canada and Europe were the five costliest events, part of a trend of more frequent extreme weather events associated with a warming planet.[1] While the consequences of global climate change are far-reaching and significant for everyone, few analyses have focused specifically on the world's middle class, an estimated one billion people.[2] We believe this is a population worthy of study, because the fate of the global middle class is fundamental to social stability and economic growth. In many countries the middle class is often the most dynamic social group. They hold more assets than lower-income groups and are more likely to take defensive action against any threat to their relative economic and social status. Should climate change be perceived of as a threat, their sheer number gives them the ability to exert political pressure.

If climate change erodes middle class wealth, the cities where they reside will also suffer economically. The world's large global cities, where nearly 25% of the global population lives, generate about half of global GDP.[3] Most of the global middle class resides in cities in Southeast Asia, which has had the fastest urban population growth in recent years. The World Bank estimates that more than half of China's population is urban, up from less than a quarter in 1985.[4] With so much of the world's population concentrated in urban areas, the health and wealth of global cities are not only crucial to a nation's economic growth, but also to the growth of many global companies.[5] The middle class matters to markets and policy, and markets and policy matter to investors.

In this UBS study we focus on how climate change affects the global middle class. Leveraging the most recent scientific data on temperature related mortality and flood risk in global cities combined with a bespoke database of middle-class household economic behavior, we evaluate the exposure of the middle class to climate change risk and the extent to which it is are adapting. Our sample includes a wide range of 215 cities across 15 countries at various different stages of economic development.

Our analysis reveals that middle-class spending patterns are noticeably different in cities that are most exposed to climate change risk. These include key global cities, such as Los Angeles, Taipei, Tokyo, Mumbai, Shanghai and New Orleans. Specifically, the middle class in high-risk cities spends around 0.6 to 0.8% more of its household budget on housing compared with the national average in their respective countries. Measured at 2014 values, middle-class households in US cities at highest climate change risk spend an average of USD 800-1,600 more per year on housing compared with a less risky city. They compensate by spending less on luxury goods, entertainment and household durable goods. We find that spending on communication, education, clothing and health is still largely unaffected by climate change.

Still, the economic effect is notable. Our measures of climate change risk are on the lower end of the range of potential risks that these cities can face, because they are based on historical average heat-related mortality and economic losses of flooding. We are not capturing the massive loss of life or assets destroyed during an extreme heat wave or flood event. For example, during the European heat wave in August 2003 there were nearly 70,000 more deaths than normal, mostly in urban areas.[6]

Devastating storm surge during Hurricane Isaac, Gulfport, Mississippi, 2012. Photo by Mike Theiss/National Geographic.

Our economic estimate also does not include the costs of other adaptive mechanisms, such as property insurance. In fact, the middle class in most of the cities in our sample is not well insured at all. Emerging markets typically have very low property insurance penetration relative to GDP: only 0.12% for China and 0.07% for India.[7] Even in the US, which has the highest insurance penetration of all the countries in our sample, one-third of weather-related losses are uninsured, according to Munich Re. Where property insurance is not available or scarcely purchased, the government is usually the "insurer of last resort." This is not free money. Between 2011-2013 the cost of US federal disaster relief for hurricanes, floods and droughts amounted to USD 400 annually per household.[8]

Air conditioning is another adaptive measure, and many households in our city sample have purchased air conditioners, especially as household incomes increase. We find some evidence that air conditioning in our city sample reduces heat-related mortality, which is in line with empirical research.[9] According to the China Statistical Yearbook, each urban household in China owned at least one air conditioner, with middle- and upper-class households seeking to own one unit per room.[10] Indeed, air conditioning sales in China doubled in the last five years.[11] However, increased use of air conditioning will drive up electricity demand and put local power grids under strain during sustained heat waves. It may also increase the very greenhouse gas emissions that are driving climate change itself—creating a vicious cycle.

Almost a quarter of the 215 cities in our study already have median annual temperatures above 20 degrees Celsius (68 degrees Fahrenheit). As temperatures reach and exceed 30 degrees Celsius (86 degrees Fahrenheit), humans have a harder time adapting—even with the aid of air conditioners—and mortality rates increase sharply in cities across the world.[12] A ten-year analysis of 15 European cities estimated that every 1 degree Celsius (1.8 degrees Fahrenheit) temperature increase above each city's average summer temperature threshold resulted in a 2% increase in mortality in northern cities and a 3% increase in southern cities.[13] In 2050, the *average* American is likely to experience 27 to 50 days over 35 degrees Celsius (95 degrees Fahrenheit) each year.[14] This is a concern for an increasingly aging population that suffers from diabetes, asthma and obesity-related disease. Infrastructure will also be stressed: planes cannot take off, rail lines buckle and asphalt melts.

Our study joins a growing body of evidence on the impact of climate change in both rich and poor countries. These studies allow us to anticipate both the rate of change and what we can expect going forward. A recent analysis of 166 countries from 1960 to 2010 revealed that labor and crop productivity peaks at an annual average temperature of 13 degrees Celsius (55.4 degrees Fahrenheit), but declines rapidly at higher temperatures. This relationship has not changed since 1960 and applies to both agricultural and non-agricultural activity in rich and poor countries—even when controlling for adaptation (usually delayed), accumulation of wealth and technology change.[15] Our analysis reveals that the middle class is adapting to climate change, but it remains to be seen if human adaption, investments in infrastructure and ingenuity can help safeguard its wealth and social status going forward.

1 Munich Re Webcast, http://www.iii.org/presentation/2015-half-year-natural-catastrophe-review-071415\.

2 Rakesh Kochhar, "A Global Middle Class Is More Promise than Reality: From 2001 to 2011, Nearly 700 Million Step Out of Poverty, but Most Only Barely," Washington, D.C.: Pew Research Center, July 2015, http://www.pewglobal.org/2015/07/08/a-global-middle-class-is-more-promise-than-reality/.

3 Brookings Institute, Global Metromonitor, 2014, "An Uncertain Recovery."

4 World Bank, World Development indicators. China's urbanization data may have an upward bias because of a looser definition of the population included in the urban area. Nonetheless, the trend is strongly positive.

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7 Swiss Re, "Underinsurance of property risks: closing the gap," Sigma report, no. 5 (2015).

8 Daniel J. Weiss and Jackie Weidman, "Disastrous Spending," Center for American Progress, April 2013.

9 Barreca et al, "Adapting to Climate Change: The remarkable decline in US temperature-mortality relationship over the 20th century," (working paper, National Bureau of Economic Research, January 2013).

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11 Lucas W. Davis and Paul J. Gertler, "Contribution of air conditioning adoption to future energy use under global warming," *Proceedings of the National Academy of Sciences* 112, no.19 (2014): 5962–5967; original source: Euromonitor International (2014) Air Treatment Products in China (Euromonitor International, Shanghai, China).

12 Gasparrini et al, "Mortality risk attributable to high and low ambient temperature: a multi-country observational study," *The Lancet* 386, no. 9991 (2015): 369-375.

13 Baccini et al, "Heat Effects on Mortality in 15 European Cities," *Epidemiology* 19, no. 5 (2008):711–719.

14 "RISKY BUSINESS: The Economic Risks of Climate Change in the United States," A Product of the Risky Business Project, 2014.

15 Marshall Burke, Solomon M. Hsiang and Edward Miguel, "Global non-linear effect of temperature on economic production," *Nature*, (2015): 235-239.

Chapter 1

2015: Another exceptional year

Natural hazards are ever present in our lives.

Anna K. Schwab, Katherine Eschelbach, and David J. Brower. 2007. Hazard Mitigation and Preparedness. Hoboken, N.J.: John Wiley and Sons.

Victims of severe floods in Pakistan, 2010. Photo by Ton Koene/Getty Images.

Several key climate change milestones occurred in 2015:[1]

The hottest temperatures ever were recorded, surpassing 2014 record-setting temperatures. Since pre-industrial times the planet has warmed by 1 degree Celsius (1.8 degrees Fahrenheit).

The strongest El Niño on record was marked by record-setting temperatures in the Pacific Ocean that were 3 degrees Celsius (5.4 degrees Fahrenheit) warmer than normal. This year's strong El Niño can be linked to drought and decreased monsoon activity in Southeast Asia, wildfires in Indonesia and an unusually active cyclone season in the northern Pacific Ocean, which experienced 21 category 4 or 5 tropical storms. By one estimate, the wildfires in Indonesia emitted as much carbon dioxide as Germany emits in a single year. If these fires continue, their emissions may reach the same level of annual fossil fuel emissions in India.

Global average atmospheric concentrations of carbon dioxide reached 400 parts per million (ppm) in May. Perhaps one of the most critical milestones, this level of carbon dioxide is 120 ppm above pre-industrial levels. Given the pace of emissions, we are currently on course to warming by at least 2 degrees Celsius (3.6 degrees Fahrenheit) above pre-industrial levels, which we hope is still safe for humanity.

Irrigating crops in record breaking drought, Cuyama Valley, California, 2015. Photo by Nik Wheeler/Getty Images.

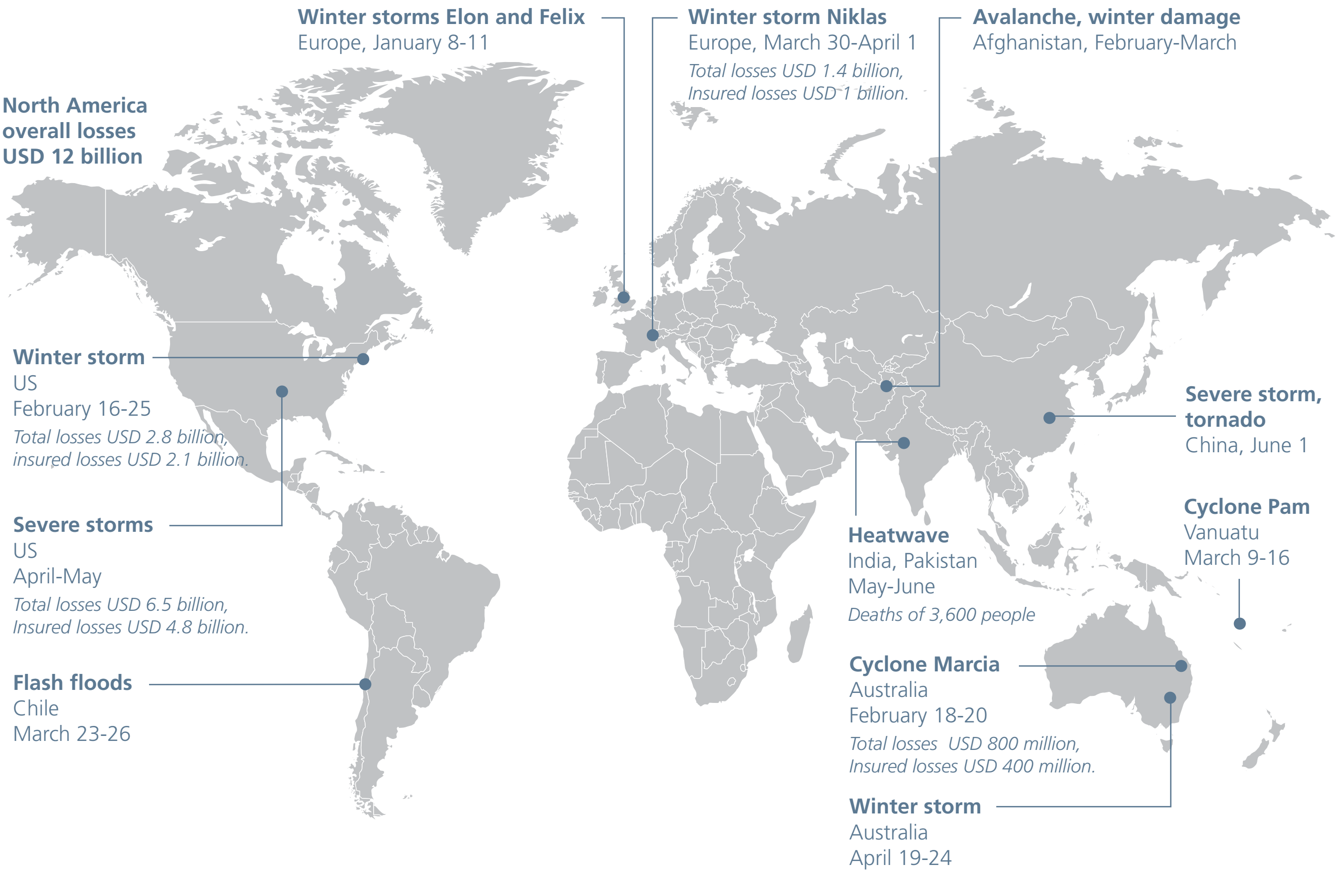
Natural hazards are ever present in our lives. However, hazards such as temperature and weather extremes can turn into natural disasters if there are people exposed to the hazard who are not resilient enough to fully absorb the impact without suffering damage to life or property.[2] For those who survive the event itself, the aftermath is often desperate. Many people are forced to leave their homes and join the growing stream of global refugees, which grew to an astounding 50 million in 2015—equivalent to Britain's population.

In already volatile situations, climate change can be what the US Department of Defense calls a "threat multiplier." For example, most of the refugees entering Europe in 2015 were Syrians with the financial resources to flee the civil war and a collapsing economy.[3] But what is easily forgotten is the record-breaking drought that plagued Syria and neighboring countries from 2006 to 2011. Temperatures in the region climbed more rapidly than the global average over the past century. Syria, already afflicted with water scarcity, saw 85% of its livestock die, crop production plummet, childhood malnutrition increase and 1.5 million people move into cities. As a result, the ensuing protests escalated into a civil war.[4]

Others suffer in place. On track to be the warmest year on record, 2015 was marked by 510 natural catastrophes in the first six months. Severe storms hit Europe, and cyclones threatened Australia and Vanuatu. In May and June, India and Pakistan were baking under temperatures that reached 47 degrees Celcius (116.6 degrees Fahrenheit), killing 3,600 people.

Across Europe, from England to Poland and Ukraine, temperatures reached upwards of 40 degrees Celsius (104 degrees Fahrenheit). Winter storm Niklas, which swept across central Europe at the end of March, was the costliest natural catastrophe in Europe, according to Munich Re. Wind speeds peaked at approximately 200 km/h, causing significant damage to buildings and vehicles.

Figure 1: Loss events worldwide January-June 2015, geographical selection of catastrophes



Source: © 2015 Münchener Rückversicherungs-Gesellschaft, NatCatSERVICE - As of July 2015.

But Niklas was not the costliest global natural catastrophe in 2015. Due in large part to the ridiculously resilient ridge (RRR), a high pressure system parked off the west coast of North America, several exceptionally cold and snowy winter storms blew down into Northeastern US and Canada in February, while preventing essential precipitation in California. Total insured losses were USD 2.1 billion. In the first half of 2015, North America experienced several severe storms during a very wet spring, resulting in losses of USD 12 billion, of which insurers bore USD 8 billion.[5] Property owners were responsible for the remaining USD 4 billion. The California drought is estimated to cost USD 2.74 billion in agricultural losses in 2015.[6]

Storms were the most costly events in 2015 to date, see Figure 2. Weather disasters are becoming more frequent and more costly, and 2015 is but the latest year in a steady upward march of extraordinary weather, see Figure 3.

Not only are higher temperatures and higher flood waters a risk, air pollution also kills. In China, an estimated 17% of annual deaths are due to air pollution from fossil fuel combustion—coal-fired power plants in particular.[7] That is the equivalent of 1.6 million people per year (about four times the population of Zurich). Air pollution kills more people worldwide than AIDS, malaria, breast cancer and tuberculosis combined.[8]

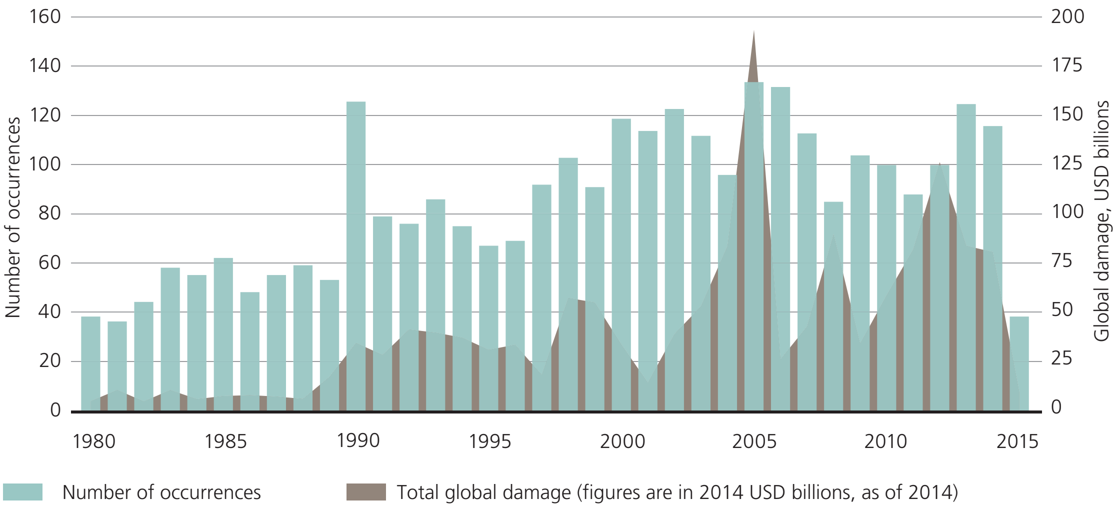
Figure 2: Loss events worldwide 2015

The five costliest natural catastrophes for the insurance industry (Jan-Oct)

Date	Event	Region	Overall losses USD m	Insured losses USD m	Fatalities
Feb.16-25, 2015	Winter storm	United States	2,800	2,100	40
May 23-28, 2015	Severe storms, flash floods, floods	United States	2,500	1,350	32
Apr. 7-10, 2015	Severe storms	United States	1,600	1,200	3
Mar. 30-Apr.1, 2015	Winter storm Niklas	Europe	1,400	1,000	11
Apr. 18-21, 2015	Severe storms	United States	1,300	940	

Source: © 2015 Münchener Rückversicherungs-Gesellschaft, NatCatSERVICE. As of October, 2015

Figure 3: USD global damage vs. occurrence (1980-2015)



Source: EM-DAT, for UBS study 31 country sample only.

1 Jason Samenow, "By one measure, this wicked El Niño is the strongest ever recorded: What it means," *The Washington Post*, November 16, 2015, https://www.washingtonpost.com/news/capital-weather-gang/wp/2015/11/16/by-one-measure-this-wicked-el-nino-is-the-strongest-ever-recorded-what-it-means/?wpmm=1&wpisrc=nl_headlines; Nature, Vol 524, 27 August, 2015, 409; Justin Gillis, "2015 Likely to be Hottest Year Ever Recorded," *The New York Times*, October 21, 2015, http://www.nytimes.com/2015/10/22/science/2015-likely-to-be-hottest-year-ever-recorded.html; Samenow, El Niño fueling most extreme tropical cyclone season on record in Northern Hemisphere, October 20, 2015, https://www.washingtonpost.com/news/capital-weather-gang/wp/2015/10/20/el-nino-fueling-most-extreme-tropical-cyclone-season-on-record-in-northern-hemisphere/; Chris Mooney, "Indonesian fires are pouring huge amounts of carbon into the atmosphere," *The Washington Post*, October 20, 2015, https://www.washingtonpost.com/news/energy-environment/wp/2015/10/20/fueled-by-el-nino-carbon-emissions-from-indonesian-peat-fires-are-rising-fast/; Adam Vaughan, "Global carbon dioxide levels break 400ppm milestone," *The Guardian*, May 6, 2015, http://www.theguardian.com/environment/2015/may/06/global-carbon-dioxide-levels-break-400ppm-milestone.

2 Anna K. Schwab, Katherine Eschelbach and David J. Brower, *Hazard Mitigation and Preparedness*, (Hoboken, N.J.: John Wiley and Sons, 2007).

3 Rod Nordland, "A Mass Migration Crisis, and It May Yet Get Worse," *The New York Times*, October 31, 2015, http://mobile.nytimes.com/2015/11/01/world/europe/a-mass-migration-crisis-and-it-may-yet-get-worse.html?emc=edit_th_20151101&nl=todaysheadlines&nlid=49249494&referer&_r=0; Lyse Doucet, "Migrant crisis: Middle classes on the move," *BBC*, September 29, 2015, http://www.bbc.com/news/world-europe-34377798; Jess McHugh, "Europe Refugee Crisis Facts: Wealthy, Educated Syrians Risking Lives To Leave War," *International Business Times*, September 9, 2015, http://www.ibtimes.com/europe-refugee-crisis-facts-wealthy-educated-syrians-risking-lives-leave-war-2089018. Before the civil war Syrian GDP per capita was as high as $5,000, more than double in Pakistan and Yemen, and five times as much as the average GDP per capita in Afghanistan. Syrian GDP has plunged 20.6% since 2011.

4 Colin P. Kelley et al, "Climate change in the Fertile Crescent and implications of the recent Syrian drought," PNAS, March 17, 2015, Vol 122: 11, 3241-3246; S. Hsiang et al., *Science* 341, 1235367 (2013). Similarly, in Egypt the revolution coincided with a surge in food prices in 2011. For a country of 80 million that heavily depends on imported wheat, a drought in China and Russia, along with Australian flooding and hoarding by various countries created a perfect storm. http://www.scientificamerican.com/article/climate-change-hastened-the-syrian-war/.

5 Robert P. Hartwig, "2015 Half-Year Natural Catastrophe Review," The Insurance Information Institute, 2015. Available at: http://www.iii.org/presentation/2015-half-year-natural-catastrophe-review-071415/.

6 "Ongoing drought to cost California $2.74 billion: researchers," Reuters, August 18, 2015, http://www.reuters.com/article/2015/08/18/us-usa-california-drought-idUSKCN0QN28520150818.

7 "Air Pollution Overview," Berkeley Earth page, http://berkeleyearth.org/air-pollution-overview/.

8 World Health Organization (2014) WHO methods and data sources for global causes of death 2000-2012. Global Health Estimates Technical Paper WHO/HIS/HSI/GHE/2014.7. Available at: http://www.who.int/entity/healthinfo/global_burden_disease/GlobalCOD_method_2000_2012.pdf; World Health Organization (2012) Burden of disease from the joint effects of Household and Ambient Air Pollution for 2012. WHO Technical Report. Available at: http://www.who.int/phe/health_topics/outdoorair/databases/AP_jointeffect_BoD_results_March2014.pdf; Bob O'Keefe, "Recent Trends in Air Quality Standards in Europe and Asia: What's next?," *HEI Annual Conference* 2013. Available: www.healtheffects.org/Slides/AnnConf2013/ OKeefe-Sun.pdf; Yang et al, "Rapid health transition in China, 1990–2010: findings from the Global Burden of Disease Study 2010." *Lancet* 381, (2013): 1987–2015.

Chapter 2

Middle-class exposure: Locating and characterizing the global middle class

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

(Intergovernmental Panel on Climate Change, 2014)

Middle-class housing units in Tokyo. Photo by GLIDEi7/Getty Images.

Understanding middle-class exposure to climate change risk depends on three factors that generally characterize many of the world's most vibrant cities: concentration of wealth, population and property value. The combination of rising oceans, more frequent storms and climbing temperatures in urban heat islands can impact global health and wealth. In this section, we examine the scope of the middle class's exposure. The interested reader is encouraged to read the Appendices for more detail on rising temperatures and flood risk. Our approach is based on a common global framework called the Intergovernmental Panel on Climate Change (IPCC) Working Group II Climate Risk Framework[1] (see definitions box).

Identifying the middle class

The term "middle class" has no precise definition in economics. If one were to try to study international spending power, or a generic global living standard, it is somewhat easier to identify the middle class by some relatively arbitrary household-income level. This is a common way of defining the middle class. But the method does run into problems. Translating incomes from one currency to another is always fraught with difficulty. The method based on international purchasing power parity that is commonly used can be criticized (not least because the rise of inflation inequality means that the conversion rate for the middle class as defined by income may differ noticeably from the conversion rate for the economy in aggregate). Furthermore, arbitrary income levels tend to skew the results towards the standards of developed economies. Emerging markets rarely have per capita income levels that measure up to developed economy standards.

Relying on occupation or profession is also a somewhat arbitrary method. For example, in some countries farmers are wealthy landowners, in others farmers have a subsistent existence and are providing directly for their families. Using education is another definition, but data is hard to come by. In addition, economies that have developed rapidly may well have a generation of entrepreneurs who would generally be considered to be middle class, but lack the markers of a formal education.

The middle class definition should be applied consistently across international boundaries, with perhaps some allowance for cultural peculiarities. It quickly becomes obvious that an income-based definition is not likely to suffice, because the middle class in one society can be politically and economically significant at a lower level of income than it is in another society. With this in mind, we define membership in the middle class by patterns of household spending to determine the lower and upper boundaries of the middle class. This fits with the established theories of the Engel curve, showing that spending on certain categories of goods and services will vary with household income (without needing to specify the exact income).

IPCC climate risk framework

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

- The lower boundary is set as consuming less than 46% of income on food and housing. Any consumer who exceeds these spending levels is assumed to be in a lower-income group given that low income consumers tend to spend most of their household budget on food and shelter.

- The upper boundary is set by spending more than 42% of income on leisure, recreation, transport and miscellaneous products, or by spending less than 34% on food and housing. Higher-income groups were historically referred to as the "leisured classes," and thus an emphasis on leisure in the household budget seems a reasonable characteristic. The food-spending criteria allows for the fact that cultural and definitional differences may compromise the use of leisure as a defining characteristic.

- The middle class is therefore the group in society that falls between these boundaries.

Using spending patterns in this way avoids the problems of converting income into an internationally standardized currency. The relative social status is captured by spending patterns. Households with these spending patterns have something to lose in a disrupted economic environment, because some element of their household spending is directed towards the accumulation of durable goods. Although there is no specification for urban residence, the data used produces a group that has an urban bias.

Choosing to focus on the impact of climate change on the middle class is not to lessen the potential impact of climate change on lower-income groups. Indeed, as a rule, lower-income groups tend to be more vulnerable to climate change than the middle class. However, once the middle class is affected by climate change, there are likely to be economic, political and/or social consequences, which are likely to prompt a policy response.

What are the characteristics of the middle class?

For our purposes, the definition of the middle class should ideally capture these four attributes:

Desire to maintain status. The middle class has a social and economic status that could be lost. This is a somewhat Dickensian definition, but it is highly pertinent to social and economic behavior. Members of the middle class want to maintain not just their absolute social and economic status, but also their relative social and economic status. Disruptive events, of any kind, threaten that status and increase the likelihood of defensive action. If climate change threatens the relative status of the middle class, the middle class will agitate for action against it.

Economically significant. This is a group that engages in a wide range of economic activities (unlike lower income groups), and yet is numerous enough that it has broad economic importance (unlike the highest income group).

Politically significant. Whether in a democracy or not, the middle class is an educated class that has influence in the state—through the ballot box, direct forms of protest or through its ability to be disruptive to the economy. This does not mean that the state will necessarily reflect the interests of the middle class in all its policies, but it does suggest that "tipping point" policy changes will take into account the interests of the middle class.

Predominantly urban. The middle class is more likely to be concentrated in urban areas and is more dependent on a relatively complex infrastructure to supply the necessities of life.

Location, location, location…

Our main geographic unit of analysis is indeed the city. By focusing on cities, we are able to leverage the most recent academic publications of the past two years that have focused on city-level effects from temperature change and weather events that cause flooding, such as the 100-year storm. Because climate change models are not precise enough, it has been very difficult to find location specific impacts. However, scholars have recently been able to estimate these effects based upon the increasing evidence of change that can be measured around the world. Our story is one of location.

We find that most of the global middle class in our 15-country sample live in cities, where middle-class wealth is indeed concentrated.[2] Figure 4 shows a ranking of 215 cities by total middle-class household wealth. Tokyo, New York, Osaka, Chicago, Philadelphia, Miami, London and Shanghai are host to a large percentage of the middle class, many of which are also considered wealthy relative to the median total household income of our city sample. Most of these cities have experienced increased wealth from 2013 to 2014, according to the Brookings Institute Global Metromonitor.[3] Beijing and Shanghai grew rapidly at 4.7% and 5.2%, respectively. Philadelphia, Miami and Washington DC were among several US cities that were still contracting. Cities that specialize in commodities, utilities, trade and tourism, and manufacturing registered the highest rates of GDP per capita in 2014, according to Brookings. Cities with high concentrations of business, financial and professional services grew more slowly.

Figure 4: City ranks by wealth concentration (Figures are in million 2014 dollars)

Middle Class Total Household Income Rank	City	Inland/ Coastal	Total Middle Class Household Income (2014 USD millions)	% Middle Class Household Income	Middle Class % Total Households	GDP/Capita Change 2013-2014 (Brookings)	Avg Annual Growth in Middle Class Household Income, 2005-2015	Climate Risk Level
1	Tokyo	C	500,336.81	52%	61%	0.70%	3.9%	1
2	New York	C	312,156.44	29%	52%	0.10%	2.4%	1
3	Osaka	C	236,520.24	51%	58%	0.60%	2.4%	1
4	Los Angeles	C	200,352.38	35%	58%	0.10%	2.3%	1
5	Chicago	I	164,368.35	37%	58%	0.70%	2.1%	1
6	Dallas	I	120,413.45	40%	61%	0.80%	3.9%	1
7	Taipei	C	116,951.89	47%	62%	2.90%	0.9%	1
8	Houston	C	107,643.79	38%	60%	1.60%	3.6%	2
9	Nagoya	C	105,537.33	44%	57%	1.00%	2.5%	1
10	Philadelphia	C	105,518.26	36%	57%	-0.50%	1.9%	1
11	Miami	C	103,552.05	43%	62%	-0.50%	1.9%	1
12	London	C	103,467.79	20%	34%	2.50%	1.6%	1
13	Shanghai	C	96,866.97	21%	31%	5.20%	8.3%	1
14	São Paulo	I	95,933.25	31%	49%	-1.50%	5.7%	1
15	Atlanta	I	95,812.13	40%	61%	1.50%	4.1%	2
16	Beijing	I	93,700.51	25%	34%	4.70%	7.4%	2
17	Washington	C	92,181.87	23%	47%	-1.50%	3.1%	2
18	Phoenix	I	81,918.62	45%	64%	0.70%	2.5%	2
19	Boston	C	79,243.84	29%	52%	0.50%	2.1%	1
20	Detroit	I	77,819.17	45%	61%	0.80%	2.3%	1

Source: Euromonitor, Brookings, UBS Analysis

The majority of the wealthy cities are located along the coasts of developed countries, where the number of middle-class households grew more slowly than in developing countries between 2005 and 2015. Some notable exceptions where wealth is more concentrated in fewer middle class-households include London, Shanghai, Sao Paulo and Beijing. All of these cities except London had high rates of middle-class income growth in the past 10 years. Of the top-20 wealthiest cities, 75% (15) were highly ranked according to temperature mortality and exposure to flood loss—a point that is critical in our study.

Figure 4 includes climate change risk hazard levels based on temperature mortality associated with median historical temperatures and flood risk exposures in these cities. A city's location is as important to climate risk exposure as its ability to attract and nurture a viable and vibrant middle class and maintain its economic strength. Based on a measure of middle-class wealth, top-ranked cities are highly exposed to risks of temperature mortality and flooding (Risk Level 1). Several critical cities in developing countries, including Tianjin, Calcutta, Guangzhou, Shanghai and Belo Horizonte, are highly exposed to climate change risk. We delve into what underlies these climate change risks below.

Climate change risk exposure

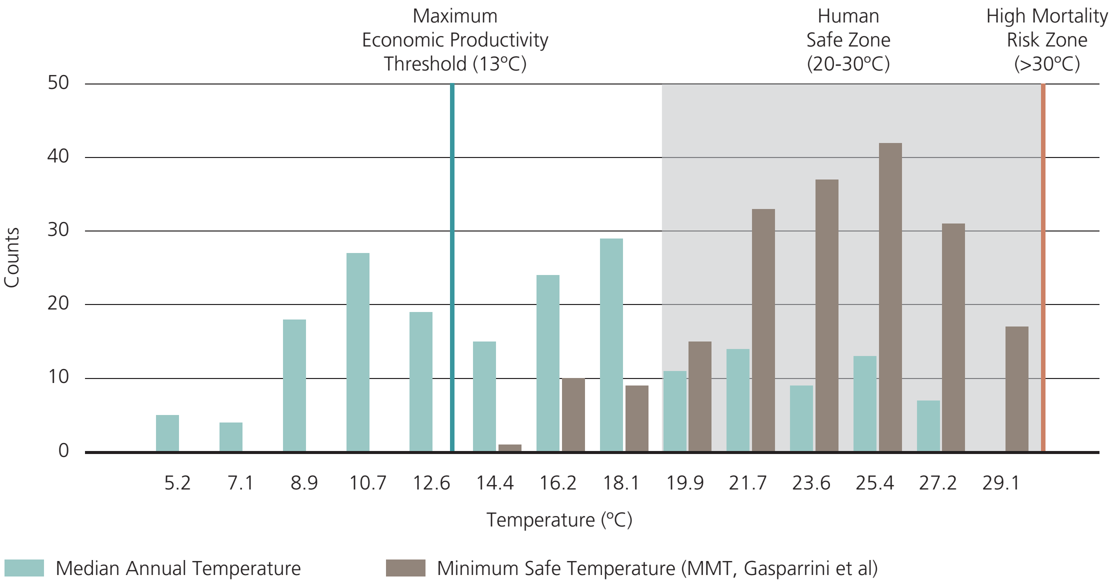
In Figure 6, we show the top 20 cities in our universe ranked by temperature mortality, flood exposure and flood losses. A wide range of cities across several regions rank highly. Certain cities, such as New York, Miami, Guangzhou, Tokyo and New Orleans, are at higher risk of heat and flooding. We derive temperature-related mortality from a recent study of global cities.[4] Our rankings for flood risk are based on another recent publication that analyzed flood losses in important coastal cities.[5] Based on 2005 data, estimated average annual global flood-related losses amount to USD 6 billion and are projected to increase to USD 52 billion by 2050 even *without incorporating climate change*. Once climate change and soil subsidence are incorporated, assuming flood protection measures remain at current levels, flood-related losses could amount to an estimated USD 1 trillion by 2050. Our ranks use 2005 flood and city exposure data.

Starting with temperature mortality, we show median annual temperatures going back to 1987. As noted earlier, more people die of heat in cities where the median temperature is usually cooler, such as London (median annual temperature 11.5 degrees Celsius, 52.7 degrees Fahrenheit), New York (median annual temperature 13.3 degrees Celsius, 55.94 degrees Fahrenheit) or Tokyo (16.7 degrees Celsius, 62.06 degrees Fahrenheit). The reason is intuitive: Humans adapt to their local climate. Even small deviations from the norm increase mortality. However, as we can see from Figure 4 there are exceptions to the rule. Some cities, such as São Paulo, Recife in Brazil, and Miami or Taipei have high heat-related mortality that is not related to extreme heat events. In these cities, median annual temperatures are close to the minimum safe temperature above and below which mortality increases. Air conditioner ("AC") possession in these cities ranges from an estimated 14.8% in São Paulo to 97.4% in Taipei, respectively. Academic research finds that having air conditioning reduces heat-related mortality.[6] However, the high relative heat mortality in cities with near complete AC penetration such as Miami and Taipei and others in a similar temperature zone indicates that humans may have limited ability to adapt to high temperatures. High temperatures combined with high humidity, as in these cities, increase mortality, particularly for aging populations. By 2100, scientists predict that cities in southwest Asia, such as Abu Dhabi, Dubai and Doha, will be so hot and humid that even extremely healthy people would not be able to survive over six hours in the open air.[7]

We discuss the relationship between high temperatures, mortality and AC possession as it pertains to our city sample more in Chapter 3. A more extensive explanation of heat mortality is provided in the Appendices to this study.

But median annual temperature is not predictive of extreme sustained heat. For example, the heat wave that hit northern Europe in 2003 was particularly deadly in French cities where the median temperatures are generally cooler and heat-related mortality is lower. This bears some explanation. Extreme heat events are still hard to predict on an individual city basis because most temperature predictions are more regional. Instead, we focused on mortality associated with the full range of historical temperatures in our sample cities. Mortality increases as temperatures drop and rise relative to the minimum safe temperature where mortality is lowest. We ranked cities by heat-related deaths for our analysis.

Figure 5: City historical temperature histograms with temperature thresholds (safe, high mortality)



Source: Gasparrini et al 2015, UBS analysis

Looking across our entire sample of cities, we find that 47% can be considered in the economically "safe" high productivity zone (13 to 20 degrees Celsius, 55.4 to 68 degrees Fahrenheit)[8] based upon median historical temperatures, see Figure 5. However, a quarter of the cities in our sample have median temperatures above 20 degrees Celsius (68 degrees Fahrenheit). These include several Brazilian cities (e.g., Teresina, Recife and Salvador), McAllen (Texas), Honolulu, Miami, Taipei (Taiwan) and Guangzhou (China). We know from the scientific literature that once temperatures exceed 30 degrees Celsius (86 degrees Fahrenheit) mortality rates increase exponentially across all cities in our sample, and certainly many more within similar temperature ranges across the world. Ten percent of our sample reached 30 degrees Celsius or higher 10% of the time in any year. Mortality increases in this temperature range, and rises sharply above 30 degrees Celsius in all cities in the sample, both in hot and more temperate climate zones.

Measured in 2005 dollars, Miami, New York and Osaka are exposed to the greatest economic losses from a 100-year flood event, with current protection levels of USD 366.4 billion, USD 236.5 billion and USD 150 billion, respectively. In terms of risk-management planning and investment, reviewing average economic annual flood losses is more useful. Guangzhou leaps to the top with an estimated annual loss of USD 687 million, which considered slightly differently, is the amount the city would have to put aside to be prepared for such an event. Miami faces average economic annual flood losses of USD 672 million. For our analysis of city climate change risk exposure, we focus on the last metric in Figure 6: average annual flood loss per city economic output (measured in 2005 dollars). This shows us how much of a city's annual economic output would have to be set aside annually to pay for future flood losses. In terms of percent of city economic output, this amounts to 1.32% for Guangzhou, 1.21% for New Orleans and 0.47% for Mumbai. In relative size, flood risk looms larger for cities in emerging markets. As sea levels rise, soil subsidence continues and storms become more violent, these cities will see increased losses, even when the frequency of flood events does not increase. Guangzhou could face average annual costs of USD 13.2 billion by 2050.

Human capital is also directly exposed to flood risk in many of these top-ranked cities. The majority of the population lives at or below 10 meters elevation in Miami (100%), New Orleans (98%), Amsterdam (99%), Rotterdam (100%), Shanghai (79%) and Guangzhou (63%), which are all cities with high asset value at risk. The combination of flood risk and higher temperatures can be expected to impact the middle class. We address this issue and how the middle class is adapting in Chapter 3.[9]

Figure 6: Top 20 city hazard rankings

Rank by Heat-Related Deaths	Median Annual Temperature (Celsius)	Minimum Safe Temperature (Celsius)	100-Year Flood Exposure (2005, USD m)	Population Below 10 Meter Elevation (2005, %)	Cities ranked by average annual flood loss (2005 USD)	Cities ranked by average annual flood loss per city GDP (2005 USD)
New York	13.3	23.1	Miami (366,421)	5,184,891 (100%)	Guangzhou	Guangzhou
Tokyo	16.7	26.5	New York (236,530)	5,209,136 (28%)	Miami	New Orleans
Rome	15.1	22.1	Osaka (149,935)	6,169,587 (45%)	New York	Mumbai
Madrid	14.2	21.9	New Orleans (143,963)	1,287,726 (98%)	New Orleans	Shenzhen
São Paulo	20.6	21.5	Tokyo (122,910)	8,707,725 (27%)	Mumbai	Miami
Osaka	17.4	26.2	Amsterdam (83,182)	969,541 (99%)	Nagoya	Kochi
Toronto	8.6	18.9	Nagoya (77,988)	1,324,968 (59%)	Tampa	Tampa
Fukuoka	17.3	25.3	Rotterdam (76,585)	864,958 (100%)	Boston	Nagoya
Philadelphia	13.6	23.3	Virginia Beach (61,507)	1,363,671 (86%)	Shenzhen	Tianjin
Chicago	10.6	24.7	Boston (55,445)	918,606 (21%)	Osaka	Xiamen
London	11.5	19.5	Tampa (49,593)	1,266,793 (52%)	Vancouver	Calcutta
Portsmouth/ Southampton	10.7	17.9	London (45,130)	1,403,489 (16%)	Tianjin	Virginia Beach
Recife	26.2	25.7	Fukuoka (39,096)	1,276,175 (46%)	Calcutta	Vancouver
Liverpool	10.1	16.2	Guangzhou (38,508)	4,987,532 (63%)	Philadelphia	Boston
Manchester	10.1	16.2	Shanghai (34,306)	10,872,620 (79%)	Virginia Beach	Taipei
Miami	25.8	24.7	Vancouver (33,456)	474,994 (23%)	Fukuoka	Fukuoka
Fortaleza	27.0	26.9	Hong Kong (26,988)	1,066,370 (16%)	Baltimore, MD	Los Angeles
Detroit	10.6	23.9	Hamburg (26,260)	516,208 (26%)	Los Angeles	Baltimore
Taipei	23.8	26.0	Mumbai (23,188)	8,525,786 (47%)	San Francisco	New York
Seville	19.0	25.7	Philadelphia (22,132)	793,597 (14%)	Bangkok	Bangkok

Source: Gasparrini et al, 2015, Hallegatte et al, 2013, UBS analysis

1 IPCC, 2014: Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32. Available at: http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf.

2 After matching our climate risk data with economic data our country sample includes: USA, UK, Spain, Japan, Taiwan, Italy, China, Canada, Brazil, Australia, Portugal, Netherlands, Finland, Germany and India.

3 Brookings Institute, Global Metromonitor, 2014, "An Uncertain Recovery." The Brookings Institute describe the economic output of a city as Gross Domestic Product., which is an approximation of the economic value added, or economic output of the city, as a contribution to the overall Gross Domestic Product of the national economy.

4 Gasparrini et al, "Mortality risk attributable to high and low ambient temperature: a multicountry observational study," *The Lancet* 6736(14) (2015): 1–7.

5 Hallegatte et al, "Future flood losses in major coastal cities," *Nature Climate Change* 3, 802–806 (2013).

6 Barreca et al, "Adapting to Climate Change: The remarkable decline in US temperature-mortality relationship over the 20th century," (working paper, National Bureau of Economic Research, January 2013).

7 Jeremy S. Pal and Elfatih A.B. Eltahir, "Future temperature in southwest Asia projected to exceed a threshold fur human adaptability", *Nature Climate Change*, Oct. 26 2015.

8 Marshall Burke, Solomon M. Hsiang and Edward Miguel, "Global non-linear effect of temperature on economic production," *Nature*, (2015): 235-239.).

9 Hallegatte et al (2013).

Chapter 3

Vulnerability: How is the middle class affected and can they adapt?

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

(Intergovernmental Panel on Climate Change, 2014)

Mahmutpasa neighborhood in the Eminönü district of Istanbul. Photo by Kivilcim Pinar/Getty Images.

Economic impact

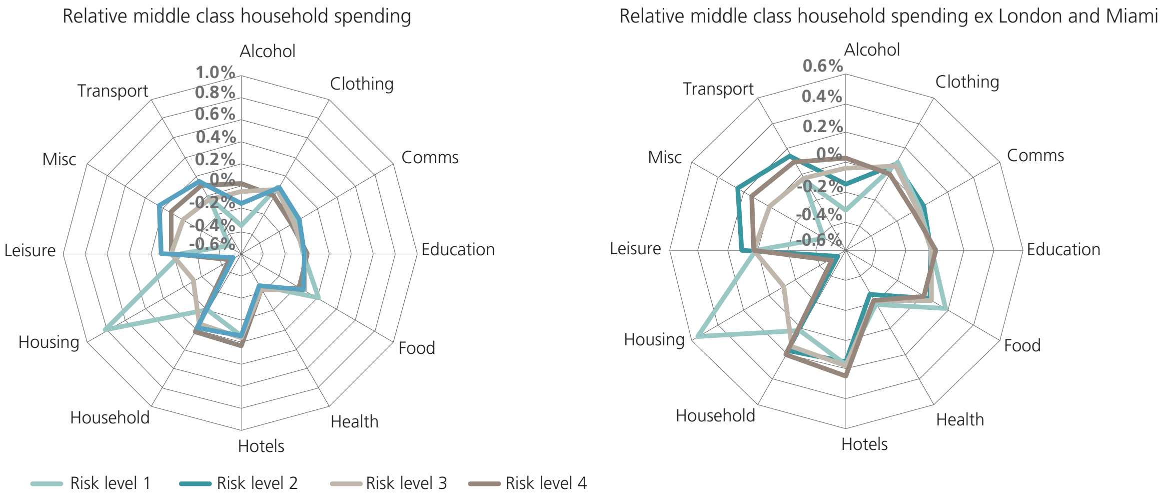
Assessing the economic impact of climate change on the middle class is fraught with complications. The middle class average has different consumption patterns around the world, and different economic structures or cultures that affect spending. For example, in the United States, the middle class spends a much higher proportion of their income on healthcare than the middle class of any other country—a fact that owes more to the inefficiencies of the US healthcare system rather than any disproportionate level of health. Focusing on the urban middle class can also create problems. In many countries, major cities have developed around sea or river ports for obvious historical reasons. The proximity to water was a necessary condition for economic growth in the past, but is a potential risk condition in a world of climate change. Their legacy of economic importance may give these cities additional attributes that are reflected in consumer spending patterns. Consumer spending on housing and leisure are obvious characteristics that may be influenced by the relative importance of a city, which could correlate with climate change risk without there being any causation. However, we need to be careful in automatically assuming that spending patterns in high-risk cities are only caused by climate change.

We have tried to filter out some of these problems in our attempt to gauge the characteristics of climate change and consumer spending patterns. First, we reviewed 215 cities across 15 countries, ranking them according to flood risk and risk of heat-related mortality—characteristics consistent with climate change vulnerability.

After establishing relative flood and temperature risk, we ranked the cities in quartiles according to the greatest risk they face. Given limited data availability and locational differences, not all cities at risk of flooding are at risk of heat-related mortality, and vice versa. We assessed the cities according to the worst-case scenario and found 62 cities that ranked in the top-quartile for flood risk, for temperature risk, or both, representing 29% of the sample universe. This group is referred to as Risk Level 1. Risk Levels 2, 3 and 4 correspond to cities where the highest-quartile ranking for flooding, or temperature, or flooding and temperature risk are in the second, third or fourth quartile.

By establishing a ranking of cities for climate change, we can try to identify any characteristics common across the spending patterns of the middle class in these cities. To remove any cultural or structural bias in a society's spending patterns, we compared the differences in spending patterns between a city's middle-class and the national middle-class average, the latter which naturally includes both rural and urban middle-class consumption. Thus we can try to identify any common relative consumption shifts associated with being a middle-class resident of a city at higher risk for climate change.

Figure 7: Middle-class spending patterns, deviation from national middle-class average, by climate risk level



Source: UBS analysis

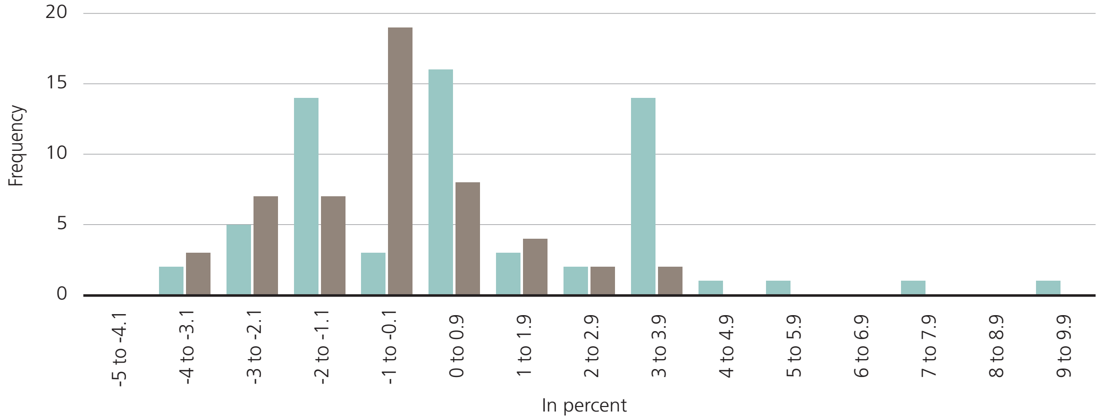
Figure 7 represents the difference in spending between the urban middle-class and the national middle-class average for each of the four risk levels, across 12 different categories of consumer spending. According to the chart, there are clear differences between the middle-class spending patterns of households in cities most vulnerable to climate change—Risk Level 1—compared with the other three risk levels. The data for spending on housing is distorted somewhat by London and Miami, where middle-class spending on housing is substantially higher than the national average. Even excluding those cities as housing outliers, the middle class spends around 0.6% more of its household budget on housing than the national average. For our purposes, housing cost represents the cost of acquiring and maintaining shelter as well as other costs associated with living in a house. It is not surprising that residents of cities exposed to higher climate change risk incur higher housing costs.

Urban middle-class spending on communication, education, clothing and health seems to be largely unaffected by climate change issues, suggesting that spending in these areas (as a share of household budget) may be relatively resilient to the effects of climate change. These four categories account for 18 to 30% of middle-class household spending, which includes disproportionate middle-class spending on healthcare in the United States.

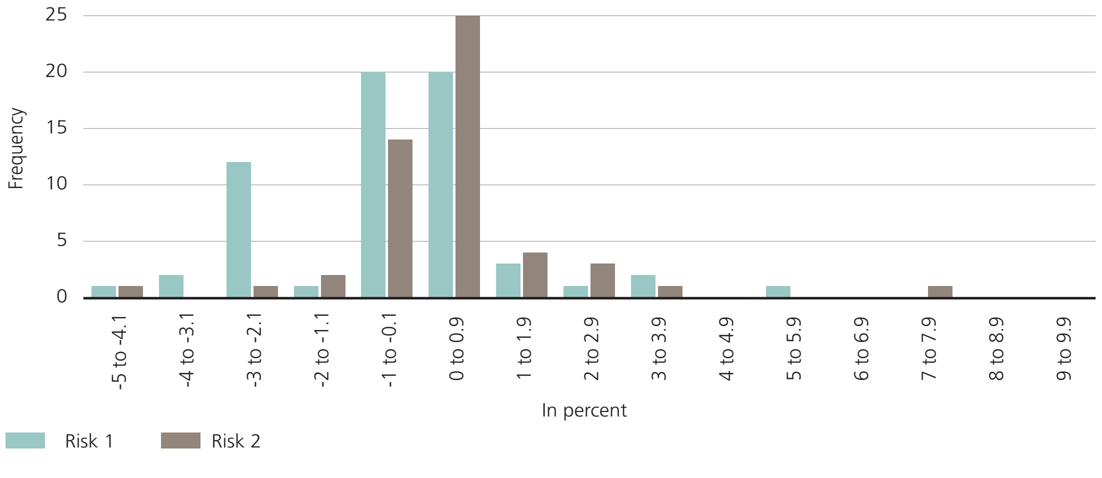
Housing cost is the largest and potentially most problematic difference in middle-class spending. The distinction between housing costs and climate change can be considered in one of two ways: 1) the appeal of living in a Risk Level 1 city declines as a result of climate change, and with that the cost of purchasing or renting a property, or, 2) the cost of maintaining a property increases as a result of climate change, and with that the property costs go up.

Figure 8: Distribution of relative middle class household spending

On housing



On miscellaneous goods



Source: UBS analysis

While a middle-class resident of a Risk Level 1 city might view this distinction as merely academic, either declining capital values or increased maintenance costs can cause a direct hit to the wealth or disposable income of the middle class. Changes in middle-class fortunes tend to be high-profile and increase the prospects of political action and a policy response. As such, the role of climate change in the housing market is likely to be the single most important issue for middle-class consumers.

Other patterns of consumer spending suggest that spending on alcohol, miscellaneous items and household durable goods is lower in Risk Level 1 cities. If climate change becomes a more significant factor for a city, these are the areas where middle-class spending is likely to be sacrificed. While climate change does not necessarily directly impact these areas of household consumption, there is likely to be more income elasticity of demand for these products. So, to the extent that housing costs are higher for cities at risk of climate change, spending in these areas is likely to be curtailed. The middle class seems (universally) more unwilling to cut back on healthcare, education and the like.

The impact of additional climate change

It is important to note that the analysis of spending patterns is conducted in a relative sense. The preceding analysis looks at how middle-class consumption in a city shifts *relative* to national average middle-class consumption for a city with a higher risk of climate change. But what happens if a city's risk of climate change increases from Risk Level 2 to Risk Level 1? We do not have data to adequately model how an individual city's middle-class spending evolves in response to a shift in its climate change risk. However, the fact that spending data in Risk Level 1 cities shows such similarities across a wide geographic and economic dispersion of cities is certainly indicative of the way climate change may affect spending.

The mode middle-class spending on housing for a Risk Level 2 city is between 0.1 and 1% *below* national average middle-class spending on housing, see Figure 8. The mode middle-class spending for a Risk Level 1 city is 0 to 0.9% *above* national average middle-class spending on housing. Therefore, it is possible to tentatively conclude that increasing climate change risk from Level 2 to Level 1 will increase consumer spending on housing by approximately 1 to 2% of the household budget. For a Risk Level 1 city in the United States, this represents a range of approximately USD 800 to 1,600 of additional spending per middle-class household, annually, see Figure 9.

Figure 9: Amount of international US dollars represented by a 1 to 2% change in middle-class spending relative to the national middle-class average, for countries with Risk Level 2 cities

Country/Region	1% difference	2% difference
China	171	342
Brazil	292	584
Italy	474	948
Canada	480	961
Japan	509	1,019
Spain	512	1,025
Australia	604	1,209
Taiwan	657	1,315
United States	795	1,590

Source: UBS analysis

While such costs are purely indicative, they provide a context for the impact a changing climate can have on the specific middle-class spending patterns. Another noticeable anomaly in spending patterns in the middle-class consumption habits in Risk Level 1 cities: lower spending on miscellaneous products. These types of goods will be relatively disposable-income elastic, which it is perhaps not surprising given that the middle class seek to economize in this area when faced with higher housing costs.

The mode distribution for Risk Level 2 middle-class spending is to allocate 0 to 0.9% more spending on miscellaneous products relative to the national average. The mode for a Risk Level 1 city is from -1 to 0.9%. Given the pattern of Risk Level 1 spending, it seems fair to suggest that middle-class consumers reduce spending on miscellaneous items in reaction to increased climate risk. Housing remains the more significant impact, however.

The economic cost of climate change for the urban middle class

Given the lack of available data, there is a certain amount of conjecture about how climate change effects middle-class spending.

Nevertheless, the relatively similar spending patterns (relative to national patterns) of the middle class in cities with climate change Risk Levels of 2, 3 and 4 contrasts to some clear shifts evident in the middle-class spending in Risk Level 1 cities.

Housing costs, which are typically the largest or second-largest nominal expense in the middle-class consumption basket, appear to be the most vulnerable to change in cities with higher climate risk. In countries with high rates of home ownership, the family home is generally a household's single most valuable asset, making the middle class more likely to be sensitive to the consequences of climate change.

Housing's relevance to the middle-class consumption basket and its cost in US dollar terms may pressure the government to socialize the costs of dealing with climate change. But if the middle class agitates for socialized protection from the cost of flooding, for example, it may lessen the personal economic incentive to contain climate change, for which there is evidence, as explained next. If the government takes on more of the cost of climate change—providing compensation for the effects of climate change to property owners —it may have greater motive to control the risks, for which there is evidence, as explained next.

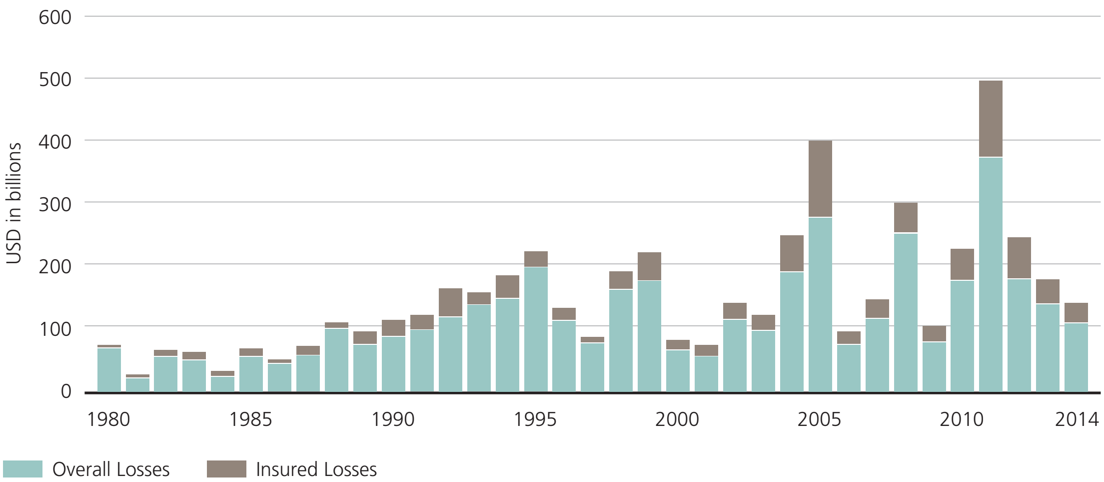
Adaptation mechanisms

The middle class's capacity to adapt depends both on how individual households can and are adapting, such as changing household spending, and on the public safety net and vulnerability of the country in which they live. Several adaptive mechanisms can help the middle class. Purchasing an air conditioner can help people adapt to rising temperatures and heat waves, reducing mortality risks. Purchasing insurance can help the middle class protect itself against property damage from extreme weather. And finally, the middle class may be able to rely on the government for disaster relief and infrastructure, such as hospitals and accessible roads to help it respond to a natural disaster, whether it be heat wave, drought or tsunami.

According to academic literature, air conditioning protects against heat mortality.[1] Our data shows that while the middle class in our cities has increased its overall ownership of air conditioners, significant differences remain, which may be due to cultural reasons and historically cooler temperatures. AC possession is mixed across the cities in our sample. For example, in some of the cities with the highest temperature mortality, AC penetration among the middle-class is still quite low, with 5% in London, 15% in Sao Paulo and 24% in Madrid. We find AC ownership is not highly correlated with middle-class household income, which reflects the fact that not all cities in our sample are in high temperature climate zones.

Increased AC penetration can help protect the middle class against higher temperatures and temperature extremes. In cities with higher AC ownership, we find some evidence that

Figure 10: Weather related loss events, worldwide (total v. insured), 1980-2015



Note: Values as of 2014 adjusted to inflation based on Country Consumer Price Index.
Source: © 2015 Münchener Rückversicherungs-Gesellschaft, NatCatSERVICE

heat-related mortality decreases. We can expect various additional factors to influence the relationship between AC ownership and heat-related mortality. These include reduced prices of air conditioning, higher electricity costs and the human ability to adapt to higher temperatures over time. However, as pointed out in Appendix 1, higher AC usage creates a whole new set of problems. AC usage increases demands on vulnerable electricity grids, boosts external temperatures and amplifies the urban heat island effect, which results in even more AC demand. Finally, and most disturbingly, greenhouse gas emissions also increase, which will in turn increase heat and AC demand. We must seek to disrupt this feedback loop if wish to have any hope of further adapting to climate change and minimizing the steady upward march of global temperatures.

Gradual temperature increases are a much underestimated silent killer. As temperatures climb, unexpected colder weather becomes a greater mortality risk. While heat waves grab more attention, even moderate deviations in temperature can increase mortality because they can occur on a daily basis throughout the year. Slight temperature variability is deadly, especially for an aging population that is obese and suffering from cardiovascular illness.

Flood risk also seems to creep up on us and is chronically underestimated, even though such events are quite common and increasingly powerful. For example, a surprisingly strong storm over Copenhagen on July 2, 2011, led to severe flooding and total losses of USD 1.1 billion. Flooding has reached levels of damage normally seen with earthquakes and tropical cyclones. The 2011 Thailand flood was the most expensive (non-hurricane) flood event in the history of the insurance industry. Only about 1% of residential homes and small commercial businesses in Thailand had insurance. Total economic damages were estimated at USD 46 billion, two-thirds of which were uninsured. Overall, the majority of weather-related losses are underinsured, a situation that has not changed considerably for decades, see Figure 10. According to Swiss Re, the average portions of uninsured losses have been steady at around 55% for windstorms, 86% for floods and 90% for earthquakes since 1975, showing little correlation with actual risks.[2] As the frequency of extreme weather events increases, and insurance rates stay flat, the portion of uninsured losses continues to grow, see Figure 10.

There are significant regional differences in insurance coverage, see Figure 11. North America continues to suffer from the greatest economic losses (44% of total global losses), due in large part to the wealth of local populations and value of the assets they own. A full 32% of weather-related losses have not been insured between 1980 and 2014. The US has the largest market with property premiums of USD 176 billion in 2014, representing 43% of the global total. The US also has high property insurance penetration; in 2014 premiums amount to 1.0% of GDP. In Canada, the sixth largest market globally, property premiums were USD 16 billion in 2014. Penetration was also high at 0.90%.[3]

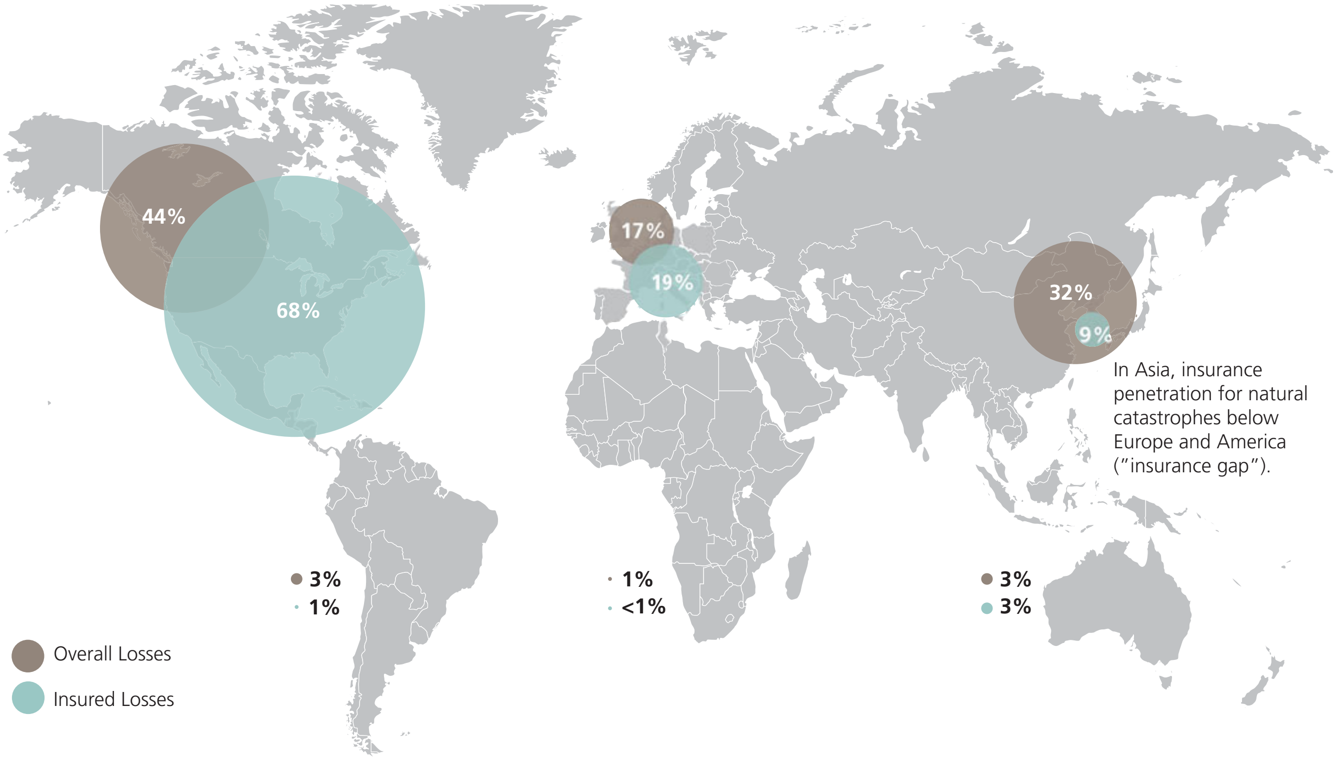
Insurance penetration is a commonly used indicator of insurance demand, expressed as gross premiums written as a percentage of GDP. Property insurance penetration tends to increase with economic development. However, this is not the case in rapidly growing emerging markets. In these countries, insurance purchases have not kept pace with the rise in property values and population growth over the past decades. In emerging markets, an average of 80–100% of economic losses is uninsured. Property insurance penetration averages around 0.21% in emerging markets, significantly lower than 0.77% in more developed markets.[4]

While Asia is highly exposed to climate risks, only 9% of losses have been insured from 1980 to 2014, according to Munich Re. China has the largest regional market with property premiums of USD 12 billion in 2014.[5] In India, insurance penetration is low because many people live in rural areas with limited access to insurance. In China, where a significant number of the population lives in urban areas, demand is also low, with insurance penetration at just 0.12% of GDP. In Japan, the fifth largest property market in the world with premium income of USD 16.9 billion in 2014, commercial and residential insurance penetration is just 0.38% of GDP, according to analysis by Swiss Re, see Figure 12.

France, the UK and Germany are the largest property insurance markets in Europe, followed by Spain, Italy and Switzerland. Penetration ranges from 0.36% in Italy to 0.81% in Switzerland. Regulation is a significant reason for these differences. For example, in most of Switzerland, building insurance is mandatory. In France and Spain, natural catastrophe insurance is covered by mandatory insurance schemes;

Figure 11: Insurance coverage, regional weather-related catastrophes worldwide, 1980-2014

Overall losses, insured losses and fatalities



Continent/ Subcontinent	Overall Losses USD bn*	Insured Losses USD bn*	Fatalities*
Total USD	USD 3,300 bn	USD 940 bn	860,000
America	1,500	650	80,000
Europe	560	180	150,000
Africa	35	2.1	35,000
Asia	1,100	83	590,000
Australia/Oceania	100	30	2,900

* Losses in 2014 values, adjusted to inflation based on country CPI.
Source: © Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE – as of January 2015.

in the UK, comprehensive property coverage is required for mortgage-financed property. In Italy, however, a high number of residential and small commercial buildings, particularly in the south, are uninsured. We summarize insurance coverage and the size of the underinsurance gap (as a percent of GDP) in Figure 12 for our sample countries, where data is available from Swiss Re.

Swiss Re estimated that total global economic losses from natural disasters have averaged around USD 180 billion annually in the last decade, of which 70% is uninsured (USD 127 billion, or USD 1.3 trillion in total over the 10 years).[6] Furthermore, the share of global uninsured property losses is estimated to rise to USD 153 billion annually. The majority of this insurance gap (USD 81 billion annual uninsured losses) is due to insufficient insurance purchases in the US, Japan and China. India, which is exposed to significant flood risk, also has low property insurance penetration. With no changes in insurance-buying behavior, we can expect the portion of uninsured losses to continue to increase exponentially.

Finally, Figure 12 includes an indicator of the ability of these countries to cope with climate change events. The Index for Risk Management (INFORM) was developed by the Inter-Agency Standing Committee Task Team for Preparedness and Resilience and the European Commission to assist with risk management. The index is structured with the same framework that we adopt here, combining indicators of hazard, exposure and vulnerability, see Figure 15. The range goes from Somalia, the least able to cope with a humanitarian disaster (9.55 out of 10), to Denmark (1.11) and Switzerland (1.14) that are most able to cope.

Country-level vulnerability is not necessarily correlated with the level of insurance penetration for our country sample, see Figure 12. And we should not be surprised. The INFORM index tracks infrastructure, healthcare sophistication and government responsiveness, all of which differ from the safety net offered by private insurance markets. Some countries

Figure 12: Country adaptation overview

Country	Middle Class % total Households	Coping Capacity (1-10)	Property premium (USD bn, 2014)	Property Insurance Penetration (% of GDP)	Estimated property underinsurance (% of GDP)
Australia	37.8%	2.21	10.7	0.73%	0.19%
Austria	30.0%	1.98	3.3	0.76%	0.05%
Belgium	40.3%	1.66	3.4	0.65%	0.15%
Brazil	41.7%	4.24	7.8	0.36%	0.00%
Canada	26.4%	2.61	16	0.90%	0.00%
China	19.0%	4.08	12.4	0.12%	0.13%
Finland	52.0%	1.70	1.3	0.48%	0.30%
France	42.8%	2.23	24.8	0.87%	0.00%
Germany	46.3%	1.76	23	0.60%	0.20%
India	40.2%	5.33	1.5	0.07%	0.13%
Italy	29.3%	2.48	7.7	0.36%	0.35%
Japan	60.9%	2.12	16.9	0.38%	0.28%
Mexico	15.6%	4.60	2	0.16%	0.17%
Netherlands	52.3%	1.40	4.9	0.57%	0.17%
Portugal	51.6%	2.85	0.7	0.32%	0.27%
Spain	34.2%	2.32	9.4	0.67%	0.00%
Switzerland	40.0%	1.14	5.7	0.81%	0.15%
Taiwan	59.5%		0.8	0.15%	0.34%
United Kingdom	42.0%	1.76	23.1	0.78%	0.02%
USA	62.1%	2.57	176.4	1.01%	0.00%

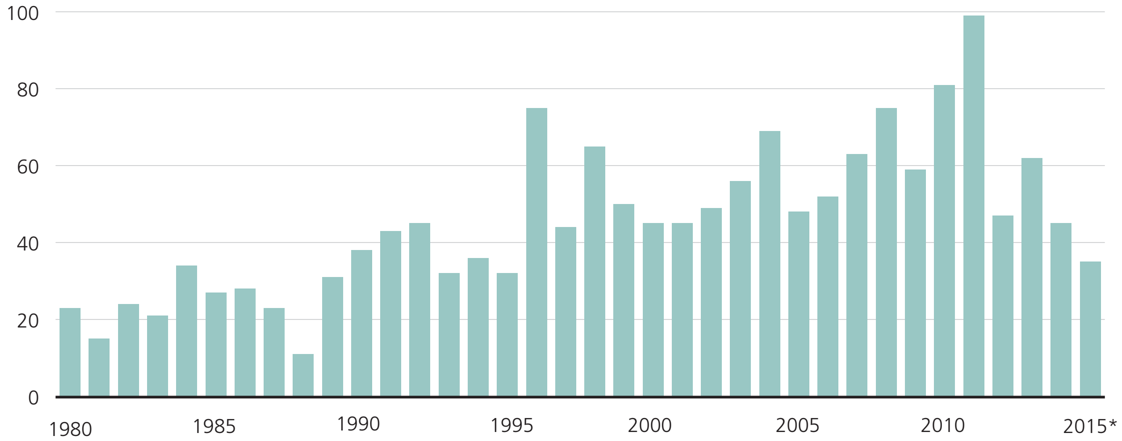
Source: Euromonitor, Swiss Re, INFORM, UBS Analysis in our sample are more vulnerable and have insufficient insurance coverage, including China, India and Portugal. On the other hand, Brazil has relatively high vulnerability (4.24), but has adequate property insurance penetration. Insurance penetration varies greatly due to different regulatory standards.

According to the INFORM index, even a rich country like the US is not able to cope as well with a disaster compared to Switzerland or Germany. This is partially due to a larger rural population and land mass in the US. While the US has the highest property insurance penetration and a large middle class (62% of total households), about one-third of economic losses are uninsured. This gap becomes a burden to the public purse, and ultimately a burden for tax payers. As the frequency and impact of disasters increase, so have US disaster declarations. Since the 1980s, the average number of disaster declarations has doubled, see Figure 13. During fiscal years 2004 to 2011, the president received governors' requests for 629 disaster declarations and approved 539 (86%). Of the approved declarations, 71% were for severe storms, according to the Federal Emergency Management Agency (FEMA).[7] FEMA committed USD 80.3 billion in relief for these 539 declarations, half of which were for Hurricane Katrina.

The costs of responding to these disasters are considerable. Between 2011 and 2013 the US government spent USD 136 billion in disaster relief for hurricanes, floods and droughts, which amounts to USD 400 annually for each household.[8] Of this amount, FEMA spent USD 55 billion on general relief and flood insurance; the Department of Agriculture spent USD 27 billion on crop insurance, due to the severe drought in the Midwest in 2012; and the Army Corps of Engineers spent approximately USD 7 billion on flood control. Hurricane Sandy (2012) was the costliest disaster in this time period. Compared to the budgets of many federal agencies, the USD 60 billion cost of Sandy (supplemental appropriation) is astounding, see Figure 14. In 2012, the US government spent more on Sandy disaster relief and recovery aid than the total budgets of many other government agencies, including the Environmental Protection Agency, National Aeronautics and Space Administration, State Department, Department of Justice and Department of Energy, to name a few.

The US must overcome systemic challenges to reduce its vulnerability to disasters. But because the federal government fails to keep accurate records of spending on disaster relief, Congress ends up budgeting insufficient funds for disaster relief and recovery. As a result, the government must respond to disasters with deficit spending. Furthermore, FEMA Individual Assistance grants, which are given directly to affected households to cover for uninsured losses of a flood event, "crowd out" the amount of insurance purchased by homeowners.[9] The crowding out effect is quite remarkable: for every 1 USD increase in average aid grants, insurance coverage decreases by an average of about USD 6. The

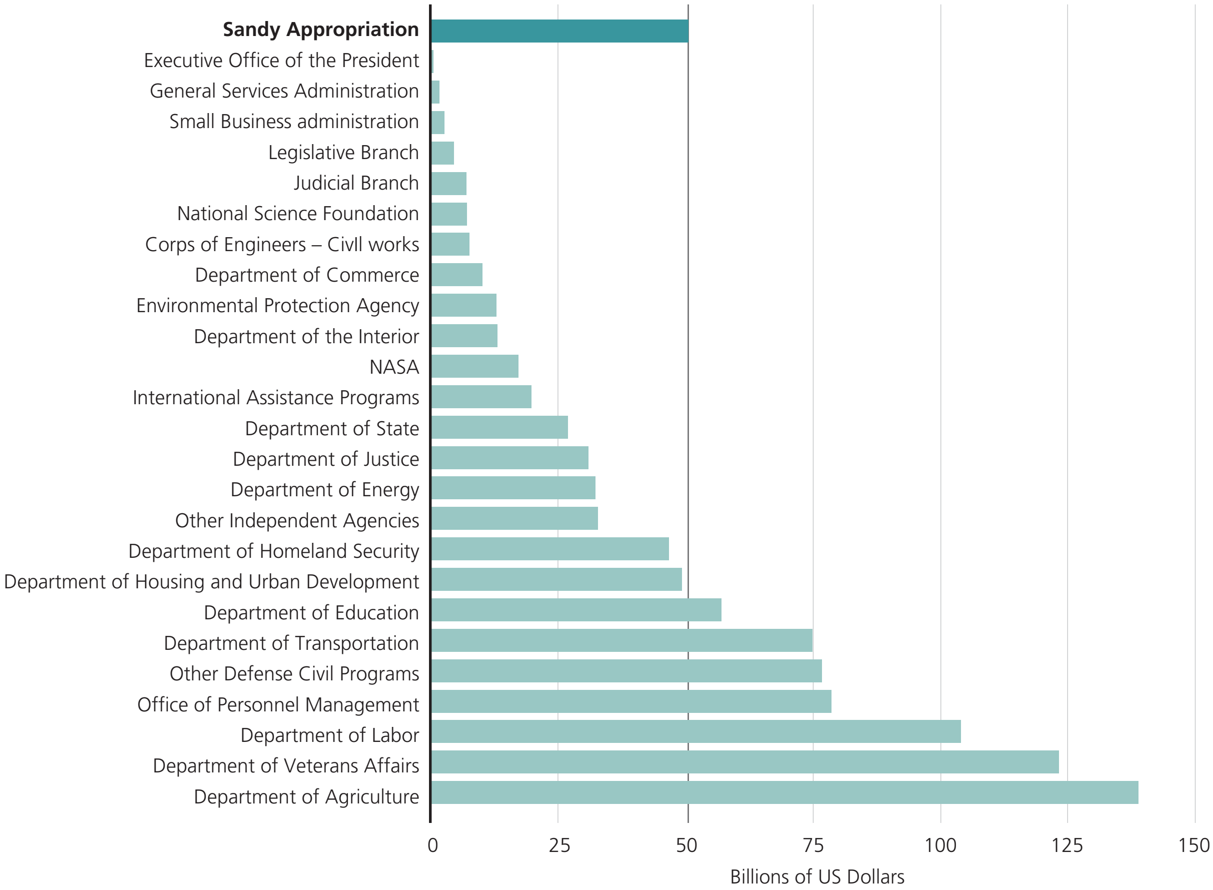
Figure 13: Number of disaster declarations, USA



The number of federal disaster declarations set a new record in 2011, with 99, shattering 2010's record 81 declarations.

Source: Federal Emergency Management Administration; http://www.fema.gov/disasters; Insurance Information Institute. *September 22, 2015.

Figure 14: Sandy supplemental compared with 2012 agency outlays



Source: Fiscal Year 2014 Historical Tables Budget of the US Office of Management and Budget, Washington, DC.
Available online at: http://www.whitehouse.gov/site/default/files/omb/budget/fy2014/assets/hist.pdf

effect is even more dramatic in neighborhoods that receive the highest average grant: for every USD 1,000 granted, insurance coverage decreases by nearly USD 18,700. Conversely, in households receiving the lowest average grant amounts, insurance coverage increased by more than USD 20,500. The greater the amount granted, the greater the crowding out effect. Without a better national strategy to tackle climate change adaptation, this ad hoc approach to extreme weather in the US will create inefficiencies and behavioral disincentives for individual homeowners. The next chapter describes some strategies that can counteract these behavioral biases that prevent individual homeowners from being better prepared to adapt to rising flood risks.

Figure 15: INFORM coping capacity metrics

Disaster Risk Reduction (DRR)	The indicator for the DRR activity in the country comes from the score of Hyogo Framework for Action (HFA) self-assessment progress reports of the countries. HFA progress reports assess strategic priorities in the implementation of disaster risk reduction actions and establish baselines on levels of progress achieved in implementing the HFA's five priorities for action.	ISDR
Corruption Perception Index (CPI)	The CPI scores and ranks countries based on how corrupt a country's public sector is perceived to be. It is a composite index, a combination of surveys and assessments of corruption, collected by a variety of reputable institutions.	Trasparency International
Government Effectiveness	Government Effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	Worldwide Governance Indicators World Bank
Communication		
Adult literacy rate	Total is the percentage of the population age 15 and above who can, with understanding, read and write a short, simple statement on their everyday life.	UNESCO
Access to electricity	Access to electricity is the percentage of population with access to electricity. Electrification data are collected from industry, national surveys and international sources.	World Bank
Internet users	Internet users are people with access to the worldwide network.	World Bank
Mobile cellular subscriptions	Mobile cellular telephone subscriptions are subscriptions to a public mobile telephone service using cellular technology, which provide access to the public switched telephone network. Post-paid and prepaid subscriptions are included.	World Bank
Physical Connectivity		
Road Density	Road density is the ratio of the length of the country's total road network to the country's land area. The road network includes all roads in the country: motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads.	World Bank
Improved Sanitation Facilities	Access to improved sanitation facilities refers to the percentage of the population using improved sanitation facilities. The improved sanitation facilities include flush/pour flush (to piped sewer system, septic tank, pit latrine), ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet.	World Bank
Improved Water Source	The indicator defines the percentage of population with reasonable access (within one km) to an adequate amount of water (20 litres per person) through a household connection, public standpipe well or spring, or rain water system. An improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter.	World Bank
Access to Health Care Index		
Physicians Density	Number of medical doctors (physicians), including generalist and specialist medical practitioners, per 10,000 population.	WHO Global Health Observatory Data Repository
Measles immunization coverage	The percentage of children under one year of age who have received at least one dose of measles-containing vaccine in a given year.	WHO Global Health Observatory Data Repository
Per capita public and private expenditure on health care	Per capita total expenditure on health (THE) expressed in Purchasing Power Parities (PPP) international dollar.	WHO Global Health Observatory Data Repository

Source: INFORM

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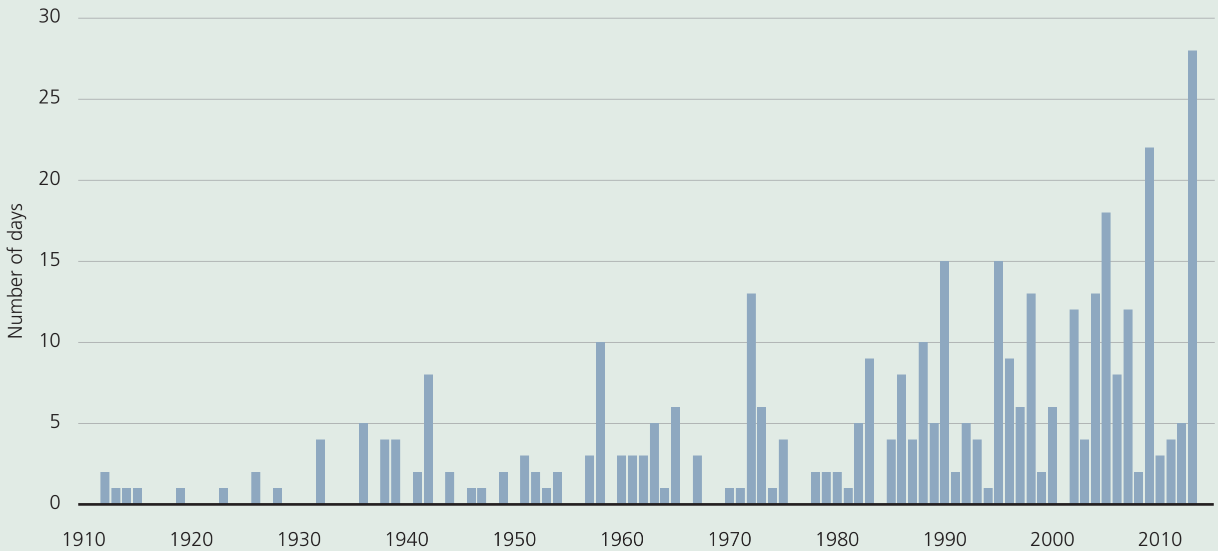
Australia: Dealing with extreme weather

Scott Haslem, Chief Economist, Head of Macro Research, UBS Australasia

Australia is a society dominated by the middle class. A recent report stated that 66% of Australia's adult population is considered middle class—the highest percentage in the world.[1] Australia is also a highly urbanized society. According to UN data, over 75% of Australians live in urban settings, the highest percentage in the world—although Australia's population density still remains one of the lowest. This concentrated urbanization reflects, in part, that Australia is the hottest, driest inhabited continent on the earth, with drought a key aspect of its climate and history. Indeed, "more Australians die every year from extreme heat than from any other type of natural disaster."[2]

There is evidence that climate change is likely making drought conditions worse in Australia, and that the situations of extreme heat (leading to more damaging bushfires) are becoming more frequent. According to Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), the annual number of 'record hot' days has doubled since 1960 and, over the past 10 years, they have been three times more frequent than record cold days. In addition, heat waves are becoming hotter, lasting longer and occurring more often than in the past. Furthermore, there is also evidence of a rising incidence of extreme storms, flooding in urban areas and coastal inundation.[3]

Figure 21: Number of days that Australian area-averaged mean temperatures were in the warmest 1% of records



The number of days each year where the Australia area-averaged daily mean temperature is above the 99th percentile for the period 1910-2013. The data are calculated from the number of days above the climatological 99th percentile for each month and then aggregated over the year. This metric reflects the spatial extend of extreme heat across the continent and its frequency. Half of these events have occurred in the past twenty years.

Source: CISRO and BoM 2014.

The impact of extreme weather (be that drought, persistent heat, extreme storms or flooding), when thinking about Australia's middle-income urban society, can be broadly categorized into three key areas:

1. Economic – largely a reflection of the impact of the increased incidence of drought, but also extreme storms, given Australia's relatively significant agricultural sector (2.5% of GDP, 20% of exports). The rising incidence of hotter weather and changing weather patterns (particularly reduced rainfall in key agricultural precincts) has significant economic impacts on both Australia's (often middle class) farmers, via reduced yields and income, while Australia's urban middle class can face temporary periods of significantly elevated food costs (especially when storms destroy mature crops). Given Australia's long history of 'drought and flooding rains', research and development as well as implementation of adaptive responses is high, albeit the recent acceleration of extreme weather has led some to questions whether change is occurring fast enough. Adaption has typically focused on developing more drought tolerant crops (bio-tech), better pasturing techniques, shifting of sowing times, water-logging strategies, tree planting and government-led programs to foster better knowledge and skills for farmers. The recent Northern Australia plan seeks to encourage agriculture in the Northwest, where rainfall has significantly increased. During the Millennium drought (1996-2010) much of urban Australia experienced severe household water restrictions as dam level approached record lows.

2. Health – health impacts from increased incidence of extreme weather are broad. They can include negative impacts on nutrition and infectious diseases; problems with food supply; loss of livelihoods; and conflict provoked by displacement and migration.[4] Research has also shown that rising incidence of drought and associated difficult farming conditions can exacerbate mental health issues, with increases in the risk of suicide for rural males aged 30 to 49.[5] While the prevalence of access to air conditioning in an advanced economy like Australia mitigates many of the health issues of rising temperatures (especially for a relatively wealthy middle-class), this is less the case for aging rural populations.[6] According to the Asthma Foundation of Australia, bushfires cause an increase in respiratory admissions to hospital while extreme storms in rural New South Wales (NSW) are responsible for concentrating grass pollens in the air which in summer and spring may be responsible for up to 50% of asthma exacerbations. Adaption has ranged from improving the quality of physical and mental health care within rural communities, water security, through to urban planning to ensure sufficient heat protection in public places.

3. Property damage – extreme heat can damage infrastructure, such as transport systems and electrical distribution, while bushfires and floods that encroach urban areas can cause significant damage (especially to housing property, a significant part of middle income Australia's net wealth). In a recent report on adaption from Australia's Department of the Environment, governance around the regulation of building codes, land use planning frameworks and regulation of energy infrastructure was highlighted as a way to promote effective adaptation.[7] There has also been increased research into bushfires and fuel management to better control fire outbreaks that damage urban property. Australia has a well-developed insurance system. For most natural disasters other than flood, insurance cover has been widely available in Australia for many years. This includes cover for storm damage, including related water damage. However, a government review was undertaken in 2011 following the flooding that occurred in many regions in late 2010 and early 2011, as it became apparent that many policyholders did not have flood cover at all or only partially. This has led to more widely available and clearer flood insurance cover. The impact of climate change through rising sea levels and coastal inundation has also been a focus given the high value of middle-income property and infrastructure located on Australia's coast line.

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Chapter 4

Strategies for dealing with climate change risks: Behavioral issues and affordability challenges

by Howard Kunreuther

Flooded streets in New Orleans after Hurricane Katrina. Photo by U.S. Air Force with Science Faction/Getty Images.

We are in a new era of catastrophes

Worldwide, economic losses from natural catastrophes increased from USD 528 billion from 1981 to 1990 to USD 1,213 billion from 2001 to 2010. Insured losses have increased dramatically as well. Between 1970 and the mid-1980s, annual insured losses from natural disasters worldwide (including forest fires) ranged from USD 3 billion to USD 4 billion. During the period 1980 to 1989, insured losses from disasters in the US averaged USD 9.1 billion annually, in 2014 dollars,[1] whereas from 2005 to 2014, insured losses from disasters in the United States averaged USD 24.7 billion annually, in 2014 dollars. When it comes to fatalities, the 10 deadliest catastrophes of 2014 occurred in developing countries, with the total number of deaths totaling over 1.5 million people.[2]

These increased losses and fatalities are due to two principal factors: urbanization with increasing value at risk and climate change impacts. In 2000, about 50% of the world's population (6 billion) lived in cities. By 2025, the United Nations projects that this figure will have increased to 60%, based on an estimated world population of 8.3 billion. The intensity, frequency and duration of North Atlantic hurricanes, as well as the frequency of the strongest hurricanes, have all increased since the early 1980s. According to the 2014 National Climate Assessment, hurricane intensity and rainfall are projected to continue to increase as the climate warms. A recent study of 850 typhoons in the northwest Pacific Ocean concluded that their ferocity will continue to increase even with moderate climate change over this century.[3] Coupled with rising sea levels, the damage from flood-related events is likely to increase significantly in the next 20 to 50 years.

This chapter focuses on the challenges and opportunities in adapting to climate change as it relates to water-related damage from floods, hurricanes and typhoons. Because of behavioral biases, we find that those at risk are reluctant to confront these hazards until after disasters occur. Recognizing these behavioral features, we discuss the role that insurance, combined with other policy tools through a public partnership, can play to address the affordability challenges facing low-income and middle-income homeowners residing in hazard-prone areas.

The primary focus is on the US, where the National Flood Insurance Program is up for renewal in 2017. However, the proposed plan of action has relevance to other natural hazards. The proposed strategy for addressing behavioral issues and affordability challenges can also be applied to other parts of the world but will need to reflect the institutional arrangements in each country and the nature of the disasters that their respective regions are likely to experience in the future.

The growing worldwide economic impact of climate change can be partially mitigated through infrastructure improvement; however the availability of insurance as well as an impetus toward more complete coverage of areas at risk has to play an important part of the adaptation to climate change. In the end though, insurance costs money, therefore populations at risk either have a less frequent but very large burden when disaster strikes or must find a way to pay for annual insurance.

Behavior with respect to extreme events amplifies the consequences of climate change

In his thought-provoking book, *Thinking, Fast and Slow*, Daniel Kahneman characterizes the differences between intuitive and deliberative thinking based on research over the past 30 years.[4] *Intuitive thinking* (System 1) operates automatically and quickly with little or no effort and no voluntary control. It is often guided by emotional reactions and simple rules of thumb that have been acquired by personal experience. *Deliberative thinking* (System 2) allocates attention to effortful and intentional mental activities where individuals calculate trade-offs, recognize relevant interdependencies and the need for coordination.

Choices are normally made by combining these two modes of thinking and generally lead to good decisions when individuals have considerable past experience as a basis for their actions. The same cannot be said about actions in response to low probability-high consequence (LP-HC) events. Empirical studies have revealed that many individuals engage in intuitive thinking and focus on short-run goals when dealing with unfamiliar LP-HC risks.[5] They often exhibit systematic biases such as the *availability heuristic*, where the judged likelihood of an event depends on its salience and memorability.[6] There is thus a tendency to ignore rare risks until *after* a catastrophic event occurs. This is a principal reason why it is common for individuals at risk to purchase insurance only *after* a large-scale disaster. A recent field survey of the risk perception of homeowners in New York City revealed that most homeowners underestimated the likelihood of water damage to their property from hurricanes. This may explain why only 20% of those who suffered damage from Hurricane Sandy had purchased flood insurance before the storm occurred.[7]

When deciding whether to invest in adaptation measures to reduce losses to property, homeowners normally do not engage in deliberative thinking. That is a comparison of the upfront costs of the measure with the expected discounted benefits over the life of the structure. There are three principal reasons that residents in hazard-prone areas have limited interest in adaptation measures: (1) they underestimate the risk and perceive the likelihood of a disaster to be below their threshold level of concern, (2) the loss reduction measures involve a high upfront cash outlay that may bump up against budget constraints and (3) they are myopic and focus on short time horizons. The reluctance to act may be compounded if they are considering moving in the next few years, which raises the possibility that the property value of their home will not reflect the expected benefits from investing in loss reduction measures because the new owner will be less focused on the risk of a disaster.[8]

An in-depth analysis of the entire portfolio of the National Flood Insurance Program in the US revealed that the median tenure of flood insurance was between two and four years while the average length of time in a residence was seven years. For example, of the 841,000 new policies bought in 2001, only 73% were still in force one year later. After two years, only 49% were in force and eight years later only 20%.[9]

Standard economic models of choice, such as expected utility theory, imply that risk-averse consumers should value insurance, because it offers them protection against large losses relative to their wealth. Indeed, individuals should celebrate not having suffered a loss over a period of time rather than canceling their policy because they have not made a claim. However, many homeowners cancel their policies, because they view insurance as an investment rather than a protective activity. Most purchase coverage after experiencing a loss from a disaster but feel they wasted their premiums if they have not made a claim over the next few years. They perceive the likelihood of a disaster as so low that they do not pay attention to its potential consequences and conclude they did not need insurance.

The decision to purchase homeowner insurance needs to be made easier. This will only work if two guiding principles are followed:

Principle 1—Premiums Should Reflect Risk
Insurance companies could provide individuals with accurate signals about the nature of the hazards they face and encourage them to engage in cost-effective mitigation measures to reduce their vulnerability. But if premiums were to increase proportionally, and above the subsidized level (e.g., US National Flood Insurance Program) to reflect risk, some residents will be faced with large price increases, driving down incentives to purchase coverage. For these reasons the second principle addresses the affordability issue.

Principle 2—Dealing with Equity and Affordability Issues
To encourage purchase, financial assistance given to individuals currently residing in hazard-prone areas who require special treatment should come from general public funding and not through insurance premium subsidies. Those who decide to locate in these regions in the future should be charged premiums that reflect the risk. This helps society avoid the trap of permanently subsidizing flood risk.

Developing strategies for dealing with behavioral issues and affordability

Because most individuals employ (and are misled by) intuitive thinking for LP-HC events, we need strategies that abide by these two guiding principles so that insurance, combined with other policy tools, can reduce future losses from extreme events. The proposed strategy involves:

- **Choice architecture** to frame the problem so that the risks are transparent and key interested parties recognize the importance of purchasing and maintaining insurance while also undertaking adaptation measures that reduce their losses from the next disaster

- **Public-private partnerships** to assist those who cannot afford to invest in risk-based insurance premiums and adaptation measures and provide financial protection against catastrophic losses for risks that are considered uninsurable by the private sector alone (e.g., flood, earthquake and terrorism)

Using choice architecture to address behavioral issues

If those residing in hazard-prone areas perceive the likelihood of losses to be below their threshold level of concern they will have no interest in purchasing insurance or investing in loss reduction measures. One way to address this problem is to recognize that people's decisions depend in part on how different options are framed and presented—i.e., the use of *choice architecture*.[10] For example, individuals might not understand what a one-in-a-million risk means, but can more accurately interpret this figure when it is compared to the risk of an automobile accident (1-in-20) or lightning striking your home on your birthday (less than one-in-a-billion). Studies have found that comparisons of risks—rather than just specifying the probability of a loss or an insurance premium—are much more effective in helping decision makers assess the need for purchasing insurance.[11] Another option is to frame the risk in terms of worst-case scenario financial consequences of being uninsured if they were to suffer severe damage from a flood. One could then provide them with information on the likelihood of the event occurring over the next 25 years rather than just next year.

Reducing losses from future disasters

If people pay attention to the risk of an LP-HC, then insurance coupled with other policy tools can incentivize property owners to invest in loss reduction measures. Risk-based premiums will give property owners accurate signals as to the degree of the hazards they face. They will also create financial incentives to invest in cost-effective mitigation measures in the form of premium reductions that reflect the lower expected claims payments from future disasters.

Means-Tested Vouchers. One way for insurance premiums to be risk-based and at the same time address affordability issues is to provide means-tested vouchers to cover the costs of protecting one's property. Several existing public sector programs in the United States could serve as models for developing such a voucher system: the Food Stamp Program, the Low Income Home Energy Assistance Program (LIHEAP) and Universal Service Fund (USF).

The amount of the voucher would be based on current income or wealth using a specific set of criteria that are outlined in a recent report by the National Research Council on affordability of flood insurance.[12] As a condition for the voucher, the property owner could be required to invest in mitigation. If the property owner were offered a multi-year loan to invest in mitigation measure(s), the voucher could cover not only a portion of the resulting lower risk-based insurance premium, but also the annual loan cost. An empirical study of homeowners in Ocean County, NJ reveals that when a structure is improved the amount of the voucher can be significantly reduced in flood prone areas.

Well-enforced building codes. Risk-based insurance premiums and means-tested vouchers could be coupled with well-enforced building codes. Following Hurricane Andrew in 1992, Florida reevaluated its building code standards, and coastal areas of the state began to enforce high-wind design provisions for residential housing. Homes that met the wind-resistant standards enforced in 1996 had a claim frequency that was 60% less than homes that were built prior to that year. The average reduction in claims from Hurricane Charley to each damaged home in Charlotte County built according to the newer code was approximately USD 20,000.[13]

Multi-year insurance. Insurers could consider designing multi-year insurance (MYI) contracts of three to five years with the policy tied to the structure rather than the property owner. The annual risk-based premium would remain stable over the length of the contract. Property owners who cancel their insurance policy early would incur a penalty cost in the same way that those who refinance a mortgage have to pay a cancellation cost to the bank issuing the mortgage. Insurers would now have an increased incentive to inspect the property over time to make sure that building codes are enforced, something they would be less likely to do with annual contracts. A web-based experiment revealed that a large majority of the responders preferred a two-year insurance contract over two one-year contracts and demanded more disaster insurance.[14]

Features of a Private-Public Partnership for insuring LP-HC events

The history of flood insurance provides guidelines for developing a private-partnership for insuring extreme events. Following the severe Mississippi River floods of 1927 no private insurer offered flood coverage, thus leading to the formation of the federally run National Flood Insurance Program (NFIP) in 1968. For private insurers to want to market coverage against the flood risk and other extreme events, the public sector will have to deal with issues of affordability, catastrophic losses and develop standards and regulations that are well enforced. The proposed features of such a program for residential property in hazard-prone areas would involve:

- Premiums that are risk-based using accurate hazard maps and damage estimates so that private insurers would have an incentive to market coverage.
- To address the affordability issue, means-tested vouchers would be provided by the public sector to those who undertook cost-effective mitigation measures. These vouchers would likely be provided to low and middle-income homeowners residing in high hazard areas
- Premium discounts would be given to homeowners to reflect the reduction in expected losses from undertaking cost-effective adaptation measures. Long-term home improvement loans coupled with grants would encourage these investments by spreading the cost of protection over time. Such a package should also be financially attractive in the short-term as the annual premium reduction is very likely to exceed the cost of the home improvement loan.
- Well-enforced building codes and seals of approval would provide an additional rationale to undertake these loss-reduction measures. Land-use regulations could restrict property development in high hazard areas.
- A multi-year insurance (MYI) policy with stable annual premiums tied to the property would prevent policyholders from canceling their policies if they did not suffer losses for several years.
- Private reinsurance and risk-transfer instruments marketed by the private sector would cover a significant portion of the catastrophic losses from future disasters.
- Federal reinsurance would be provided to insurers so they are protected against extreme losses.

The benefits of this proposed program would be significant: less damage to property and potentially higher property values, lower costs and peace of mind to homeowners knowing they are protected against future disaster, more secure mortgages for banks and financial institutions, and lower disaster relief assistance by the public sector borne by the general taxpayer. It will also address the climate change problem by encouraging homeowners to undertake adaptation measures today such as elevating or flood-proofing their property so they reduce or eliminate flood-related damage to their property from the next hurricane or flood. While designed with the US market in mind, changes to the NFIP could serve as a model for dealing with other LP-HC events in the US and other countries.

Flood insurance in other countries

Recognizing the growing interest in improving resilience to flood risk around the world and the role that insurance can play in that regard, several countries are debating what national flood insurance solutions they should have in place, or how to improve the current situations. Insurers are also fully involved in those discussions, either because they cover the risk; partner with the national government in doing so by underwriting, selling policies, adjusting claims after disasters; or because they are contemplating market opportunities.

A recent paper by Atreya et al reviews homeowners' flood insurance in 25 countries including: the role of the public and private sectors; design choices (required or voluntary insurance, bundled with other coverage or standalone, pricing determination), elements of market penetration (typically fairly low unless requirements are in place, and enforced); links between insurance and mitigation efforts (which are relatively poor in most countries, except the US) and other features in describing the similarities and differences across the national solutions.[15] The "best" design or features will depend on the specificities and culture of the country under study.

Conclusion

Insurance needs to play a central role in the adaptation to climate change. If the US population is underinsured, less affluent populations in South Asia are even more underinsured and even less aware of the potential risk. Moreover, their economic circumstances make the purchase of insurance that accurately reflects risk an expensive purchase without obvious immediate benefits. It is therefore imperative that the governments in the affected regions take a much more proactive approach toward insurability or suffer significant economic shocks because of disaster that can derail economic growth for many years.

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Conclusion

The global business and political community is increasingly aware of the risks of climate change. Climate change related concerns have risen to the top of the World Economic Forum's (WEF) Global Risk rankings in recent years. In 2015, the top-ranked risk was interstate conflict, such as the Syrian civil war that has escalated into a global concern.[1] Research has pinpointed the causative role of drought in the eastern Mediterranean in sparking that conflict.[2] Water crises and failure of climate-change adaptation are fast followers on the WEF ranking. We find many data points in recent scholarship that show the consequences of climate change. Without adaptation, scientific predictions of our future are sobering.

Citizens across the globe are equally aware and concerned. The Pew Research Center found that more than half of citizens surveyed in 40 nations consider climate change a very serious problem, and 40% are very concerned that climate change will harm them personally.[3] A majority also believe that climate change is harming people now. Concern varies greatly across the globe with respondents in Latin America and Africa being more concerned than those in Europe and Asia, probably because of a higher level of perceived economic fragility. There is meaningfully less concern in the US and China, compared to the global medians, though almost half of the Chinese respondents believe climate change is harming people now. The majority (78%) of respondents would be supportive of an international agreement to limit greenhouse gas emissions.

Despite the fact that surveys can identify a base level of worry, the connection with the present-day is not so evident, making near-term action to abate risk from climate change politically and socially difficult. One important reason is that climate change has usually been presented and thought of as a problem in the long term—end of century or mid century. But 2050 is only 35 years away. Many of today's citizens will be alive then. This means that the population that has to act today is, in fact, much of the population that will be affected tomorrow.

Our purpose in writing this research study is to move from a macro, high-level panorama to a more intimate view of the middle-class household. Scientific research of the past two to three years has enabled us to pursue a granular, localized city-level analysis. This analysis paints a picture of increasing risk to middle-class household wealth and economic standing as well as the effort to adapt to climate change effects, in the context of geography, infrastructure development and industrial development. The home is typically a large component of middle class family wealth, and either the asset is at risk from climate change, or consumption patterns will have to change significantly to defend (insure) the value of the asset from climate change. Our analysis reveals that of the 215 cities in our sample, middle-class households in the highest climate risk quartile are spending more on housing. We also find mild support for the protective effect of air conditioning against heat-related deaths in these cities. We are limited in our ability to delve more deeply into the nature of these relationships due to lack of data—an interesting area for future research.

Climate change is a disruptive force in the global economy. While many of the direct effects of climate change are localized, the global interconnectedness of economies and supply chains means that a flood or disaster in South Asia can directly affect the world economy, exposing the developed world to goods shortages, supply interruptions, financial instability and negative wealth effects. Who would have thought that a flood in Thailand would affect the entire personal computer and data storage industry in 2011?

The middle class is adapting to these forces. However, in many of the countries in our sample, adaptation is still modest and is inadequate compared to actual exposure to climate change. Many of the fastest-growing cities in the world (especially in Asia), where the middle class of the future resides, are exposed to significant flood risks, and are either uninsured or underinsured. The developed world has a tendency to be underinsured, but the developing world is even less protected from catastrophic loss because insurance is either unavailable or not affordable. Moreover, protective infrastructure in these countries is weak or lacking. Lack of protection increases the economic consequences of climate induced disasters locally and this effect may have implications for the global economy. Furthermore, economic development increases the mass and value of physical infrastructure, making the effect of storms or floods much greater and costlier to repair.

According to the Pew Survey, global citizenry believe that they will need to change their lifestyle as a consequence of climate change. In our assessment, the middle class is already doing so in cities exposed to the highest level of climate change risk. More fear, less fun is how we might sum it up. They spend more on housing related costs (e.g., upkeep) and cut down on durable goods and services, entertainment, luxury items and financial services. Fear, because attempting to adapt creates a negative feedback loop. During prolonged periods of rising temperatures—of ever greater frequency—the demand for air conditioning requires more electricity (absent better building practices and greater cooling efficiency). More electricity demand can trigger grid failure and increases the very greenhouse gas emissions that drive climate change unless incremental power is generated by clean methods. In China, incremental power generation is primarily from clean sources but this is not true of India, which is on track to more than double its coal production by 2020.[4] Fear, because inadequate infrastructure and health care systems increase the need for reliance on emergency government support. In our assessment this is likely, even in the richest of countries.

The economic evolution of the middle class in warming, flood-exposed Asian cities means that the same impetus that raises comfort levels and living standards through household spending and home ownership amplifies the chance of catastrophic economic loss. Some of the economic impact may be redistributive rather than absolute, but either way, the middle class is unusually vulnerable to the risk of adverse economic consequences.

The relative political and social importance of the middle class means that this vulnerability should translate into pressure for a policy response. The only force that can push back on these trends is a real effort to limit carbon emissions and reduce the greenhouse gas effect. Therefore, the forces that make the middle class suffer and adapt to climate change are the same forces that are likely to stir the middle class to political activism. We conclude that climate change risks are real to the middle class—and for this reason, we are hopeful that this will translate into positive, meaningful and lasting action to reduce carbon emissions worldwide.

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Appendix 1

Hazard: Global temperature rise and human health

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

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Extreme temperatures and pollution haze over residential complex in China. Photo by Juny Yeung/Getty Images.

Temperature and human health

Temperature extremes and heat waves are increasingly contributing to mortality around the world. Figure 1 shows extreme temperature events and associated deaths between 2000 and 2015.[1] In the Netherlands, mortality increased from 9 to 25% due to heat waves between 1979 and 1997.[2] Mortality also increased as a result of cold spells, ranging from 10 to 27% above baseline. Certain subpopulations are more susceptible: older individuals, those with compromised health, those with low income, and more broadly, urban dwellers, see Figure 2.[3] Even when they don't kill, heat waves are a health threat. In California, between 1999 and 2009, hospital admissions increased by 7% during heat waves with notable differences observed between regions and among certain diseased subgroups.[4]

These trends are concerning given aging populations. Globally, the number of persons older than 60 years is expected to rise from 841 million in 2013 to over 2 billion by 2050. Most of these individuals will be living in developing countries. As people live longer and have fewer children, there will be a greater strain on health and social insurance systems. There will also be economic challenges related to a diminishing labor supply.[5]

Temperature change will also have consequences for the growing portion of the global population that is chronically ill. People with diabetes have a greater risk of mortality with increasingly extreme temperatures. Non-communicable diseases, such as diabetes and cardiovascular disease, are rising. The number of known cases of diabetes worldwide was 171 million in 2000. By 2030, the number is expected to reach 366 million, largely in populations 65 years of age and older. The greatest increases are expected in sub-Saharan Africa, Eastern Mediterranean and Southeast Asia.[6]

The city is an increasingly dangerous place during heat waves. Large expanses of asphalt and limited green space contribute to a localized increase in temperature called a 'heat island effect' (HIE). Temperatures in urban centers can increase up to 3 degrees Celsius (5.4 Fahrenheit), relative to surrounding more rural areas. Consequently, the risk of heat-related mortality increases exponentially. Air-conditioned spaces are protective during these extreme heat events; however, the waste heat generated from the air conditioning (AC) units contributes to higher street level temperatures. AC usage creates a vicious cycle where increased heat drives energy demand and ultimately increases CO_2 emissions (from fossil fuel combustion for electricity).[7] Metropolitan areas are also often burdened by air pollution, which increases mortality. Emissions

Figure 1: Extreme heat events and mortality

Start Date	End Date	Country Name	Total Deaths
6/1/10	8/1/10	Russia	55,736
7/16/03	8/15/03	Italy	20,089
8/1/03	8/20/03	France	19,490
8/1/03	8/11/03	Spain	15,090
8/1/03	8/1/03	Germany	9,355
8/1/03	8/01/03	Portugal	2,696
5/26/15	5/31/15	India	2,500
7/15/06	7/23/06	France	1,388
6/18/15	6/24/15	Pakistan	1,229
5/14/03	6/6/03	India	1,210
8/1/03	8/15/03	Belgium	1,175
7/1/03	7/01/03	Switzerland	1,039
5/10/02	5/22/02	India	1,030
7/15/06	7/23/06	Netherlands	1,000

Source: Guha-Sapir D et al. EM-DAT: Int'l Disaster Database come from a various sources concentrated in a small area, including transportation, residential and industrial sectors. Air pollution and high temperatures only serve to amplify the risk of death during a heat wave. If both conditions occur simultaneously, public health officials may recommend that urban residents stay indoors during a heat wave, but this can increase mortality risks for those who do not have air conditioning.[8]

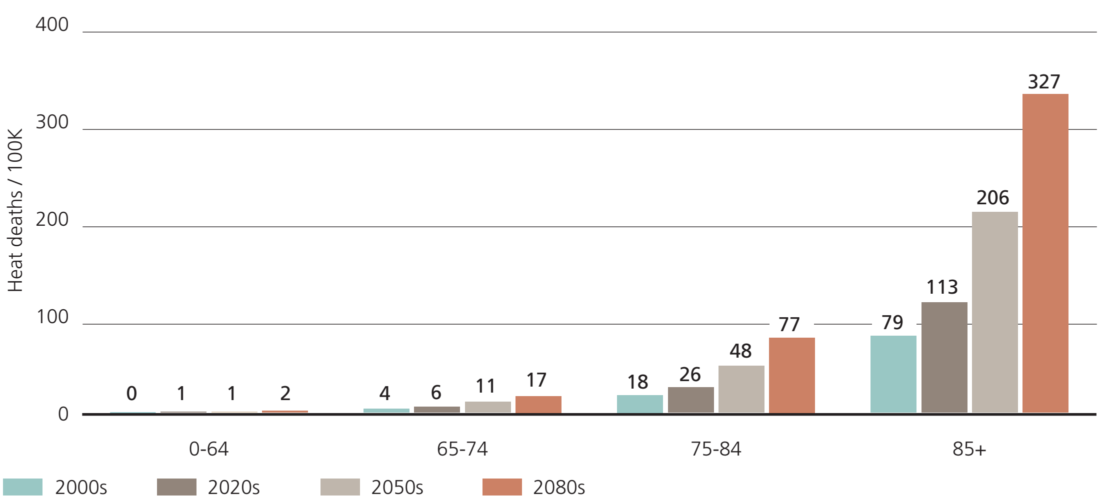
Systemic breakdown—cascading failures during the European heat wave, 2003

A breakdown of social and public support systems, insufficient infrastructure and extreme weather can create disastrous results in the urban environment.[9] The historic European heat wave of 2003 is a tragic example. Between August 4 and August 18, 2003 nearly 15,000 people died in France alone as a result of an extremely intense heat wave, see Figure 3. The severity and duration resulted in loss of life due to the direct effects of dehydration, hyperthermia and heat stroke and other systemic failures. The elderly and those with pre-existing diseases were more affected. However, increased mortality was higher for age groups as low as 35 years and older. Mortality was greater in home environments compared to hospitals. Over half of those who died lived on the top two floors and one third lived 'under the roof'. These small 'service rooms' lacked ventilation and insulation and were exposed directly to the sun by skylights resulting in stiflingly hot temperatures, exceeding 40 degrees Celsius (104 degrees Fahrenheit). Economic poverty and social isolation exacerbated the problem, with most of the mortality occurring in widowed, single and divorced populations. Social connectedness and reluctance to follow educational and public health warnings also contributed.[10] France was not the only country affected by this heat wave. In Italy, low socioeconomic status, the elderly and those less educated suffered the greatest losses, with an 18 to 43% increase in mortality.[11] Similarly, during the 1995 Chicago heat wave factors increasing mortality included advancing age, medical problems, living on top floor of a building and living alone.[12]

Why is temperature so dangerous?

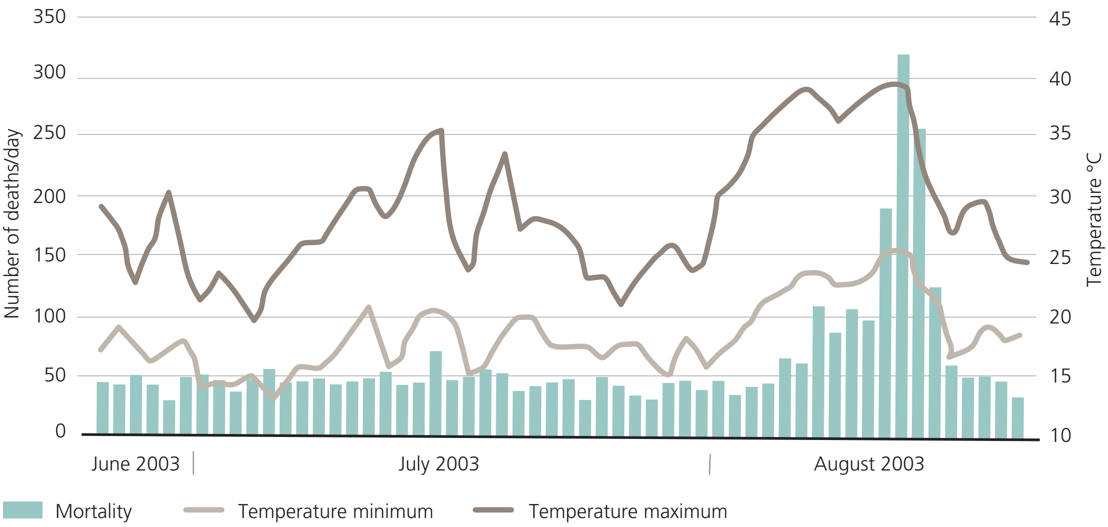
Extreme heat significantly challenges the human body's ability to maintain an optimal core body temperature (37 degrees Celsius, 98.6 degrees Fahrenheit). Under normal circumstances, the cardiovascular and respiratory systems dissipate heat through the skin as sweat to balance the combined heat produced by the body and received from the environment.[13] Behavioral factors are also important in managing temperature and include: hydration (maintains blood pressure for normal organ function), appropriate clothing, limited activity and access to cool spaces. These adaptations are generally effective solutions. However, inability to afford air conditioning or limited mobility to reach air-conditioned space can alter successful management of body temperature. Additionally, when both temperature and humidity are high,

Figure 2: Heat-related deaths in the UK



Source: S. Hajat et al, 2014

Figure 3: Heat mortality in France, 2003



Source: Doussett 2011

sweating efficiency is compromised, making it difficult to dissipate heat, which results in dangerously high internal temperatures.[14] Compromised individuals with improperly functioning systems have greater difficulty maintaining a safe core temperature. An inability to regulate temperature has dire consequences including organ failure and death.

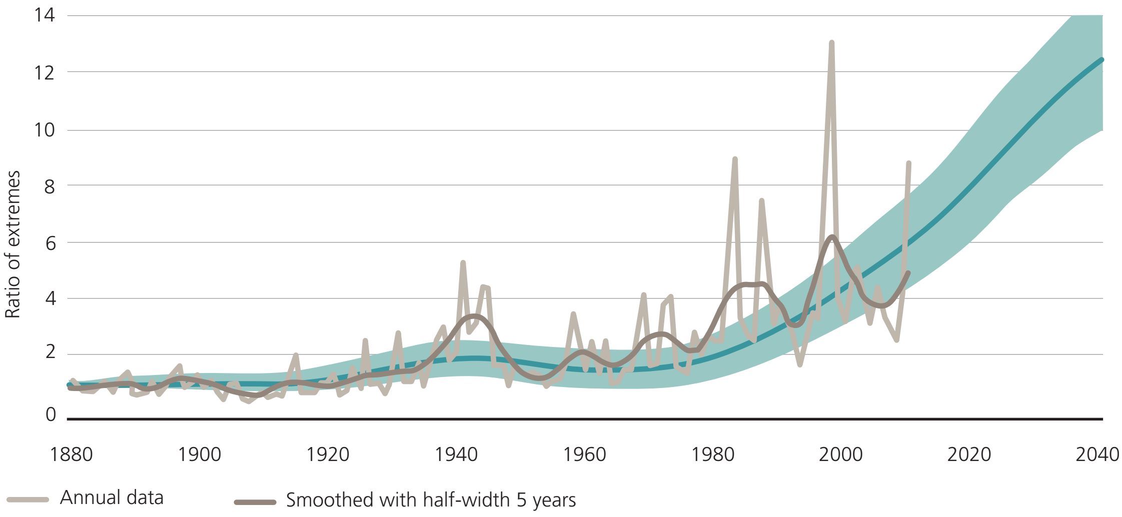
Successful human adaptation to extreme temperatures relies upon physiological competence as well as socioeconomic and societal influences. Under controlled circumstances with appropriate care (fluid replacement, rest), healthy populations can adapt to extreme temperatures *over time*. Nevertheless, there are real physical limits even for healthy populations. Additional factors that result in higher mortality during extreme weather events include social isolation, poverty and race.[15]

Extreme heat is not our only concern.[16] Global temperatures are becoming more erratic, see Figure 4.[17] Though populations are generally accustomed to the temperature of their environment, unexpected deviation from this temperature can contribute to an increased number of deaths over the baseline. The 'optimum temperature' is defined as the minimum mortality temperature (MMT), which is the temperature with the lowest related mortality rate. Temperature swings in either direction can result in a greater number of deaths, especially when cultural, physiological and behavioral mechanisms get in the way. A higher death rate in response to unusual fluctuations in temperature can suggest a lack of population adaptation. This effect is most notable in regions accustomed to cooler temperatures where heat waves are more difficult to manage. However, as these regions warm under climate change conditions, cool weather deviations also increase mortality. The impacts of moderate temperature shifts away from the MMT are meaningful given to the sheer number of days this occurs in comparison to heat.[18] This makes temperature variability an important driver of mortality. A special case of variability is when extreme temperatures occur early in the season. In the US, between 1987 and 2005, the 'first of the season' heat wave mortality was 5.04% (over baseline) compared to 2.65% for later season heat waves.[19]

Predictions, trends and adaptations

Measuring and predicting mortality to a changing temperature, changing demographics and a changing landscape are intrinsically complex. Geographic differences result in different manifestations of climate change. Increases in heat wave intensity and timing are expected in different parts of the world.[20] More susceptible areas include historically cooler climates of northwest US, France, Germany and the Balkans.[21] For example, on June 28, 2015, several cities in the northwest US experienced all-time record high temperatures including Chelan, WA at 43.3 degrees Celsius (109.9 Fahrenheit) and Chief Joseph Dam, WA 45 degrees Celsius (113 Fahrenheit). In Europe,

Figure 4: Observed monthly heat records, 1880-present



Source: Coumou 2013

Kitzingen, Germany hit 40.3 degrees Celsius (104.5 degrees Fahrenheit), setting a new record.[22] Unfortunately, extreme heat waves are expected to increase by a factor of 5 to 10 in this region by 2050.[23]

Other regions will face conditions that threaten the biological thresholds of humans and their ability to adapt. Places with high humidity in Southwest Asia are likely to become inhospitable for human settlement. By the end of the century, a 'normal summer day' in the Persian Gulf could be too hot and too humid for survival of more than six hours without employing externally derived adaptive strategies. For emerging economies with limited financial resources and underdeveloped infrastructures, adaptability will be challenging if not impossible.[24] Given the large labor and construction workforce that is directly exposed to rising temperatures in India, heat wave intensity is expected to seriously impact productivity and population health.[25] For example, more than 2000 people died in India when record-breaking temperatures reached 48 degrees Celsius (118.4 Fahrenheit) in July 2015. Hospitals faced long queues and periodic power cuts that limited access to air conditioning.

Forecasting heat-related mortality is challenging and results in a broad range of predictions. Projections for heat or heat waves range between 70% and 300%. In the UK, mortality from heat waves may increase up to 257% by 2050 accounting for a susceptible aging and growing population, without including adaptation. Globally, from 2000 to 2100, the projected increase in mortality risk from heat stress ranges from 100 to 1000%. Disparity of the burden is noted between countries, with the most significant excesses predicted in China, India and Europe.[26]

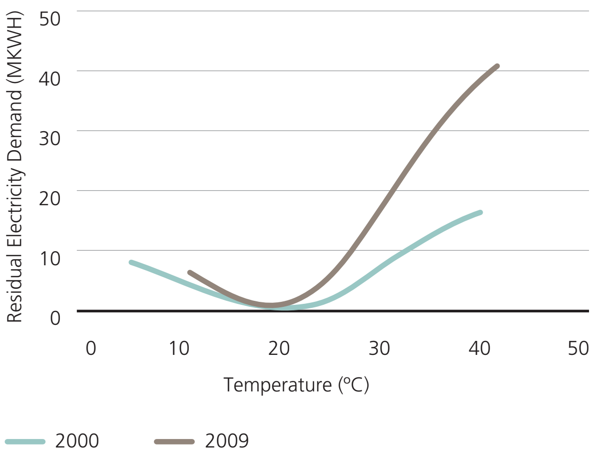
Adaptation at a population level is difficult to predict. For an individual, physiologic responses will have varying degrees of success. Persons with diseased systems are particularly susceptible to both mortality and morbidity from heat stress, and this population is changing. For the general public and vulnerable subpopulations, early warning systems, education and call systems can reduce overall risk via community level adaptation strategies. Increased public awareness and an improved warning system put in place after the devastating 2003 heat wave that killed nearly 15,000 people in France may have decreased the loss of life in the 2006 heat wave.[27]

The use of air conditioning is the most successful adaptation strategy of the late 20th century and early 21st century, having reduced the heat mortality by approximately 70%. In the US, AC utilization is roughly 80% (higher in some regions of the south). However, as warm temperatures creep north in latitude, there are opportunities to protect more people in regions where AC utilization is low.[28] For emerging economies, where AC penetration is much lower, the opportunity for expansion is enormous and poised to reach near saturation in the next few decades as incomes rise. For example, sales of air conditioners in China have nearly doubled over the last five years. The growth potential for other low-income countries is even greater, especially when accounting for the number of cooling days in many of these states.[29]

The requirement of electricity is a massive concern with increasing AC utilization, see Figure 20.[30] By one estimate, electricity consumption increases by roughly 64% with carbon dioxide emissions increasing proportionally under a business-as-usual scenario.[31] The strains on local electricity grid will also increase.[32] Power cuts left 600,000 people without electricity during an intense heat wave in France in late June and early July of this year.[33] In the US, power shortages are predicted as early as 2020.[34]

Electricity provision will suffer during extreme events such as heat waves and storms related to climate changes. The large, interconnected

Figure 20: Estimated temperature electricity curve for Delhi, India



Source: Gupta 2012

Residential tower with air conditioning units, Hong Kong. Photo by Emma Durnford/Lattitude Stock.

structure of electrical grids makes them vulnerable for several reasons. One, power plants are often placed near coastlines placing them at increased risk of damage from storms. Two, most power plants require water for cooling. Continuous delivery is compromised under intense drought conditions. As temperatures rise, power plant efficiency can decline.[35] Third, a consistent supply of necessary fuel may become more difficult to obtain depending on the country's resources, both financial and natural. When Hurricane Sandy impacted the Northeast coast, damage to the grid resulted in more than eight million customers losing power.[36] In the summer of 2011, record-breaking heat and drought conditions in Texas resulted in the closure of many coal and natural gas plants due to their dependence on available water.[37]

Global temperature rise—indirect human health risks

The direct hazards of temperature extremes are clear. However, indirect effects will also rise, touching every aspect of human society. High temperatures and climate change will impact agriculture, food prices, social security and water availability.[38] Rising sea levels with increasing populations in coastal urban environments will put billions of people in harm's way. Scorched landscapes and drought conditions will contribute to massive wildfires, exacerbating air pollution and health risks. These risks are mounting while human contributions continue at an unprecedented pace. The effects of climate change undermine the pillars of population health, the economy and society. It is therefore imperative that we understand how these conditions have and will impact human systems on a global scale. Identifying contributions, connections and solutions are imperative to insure they are sustainable and available to all.

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Appendix 2

Hazard: Extreme weather

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

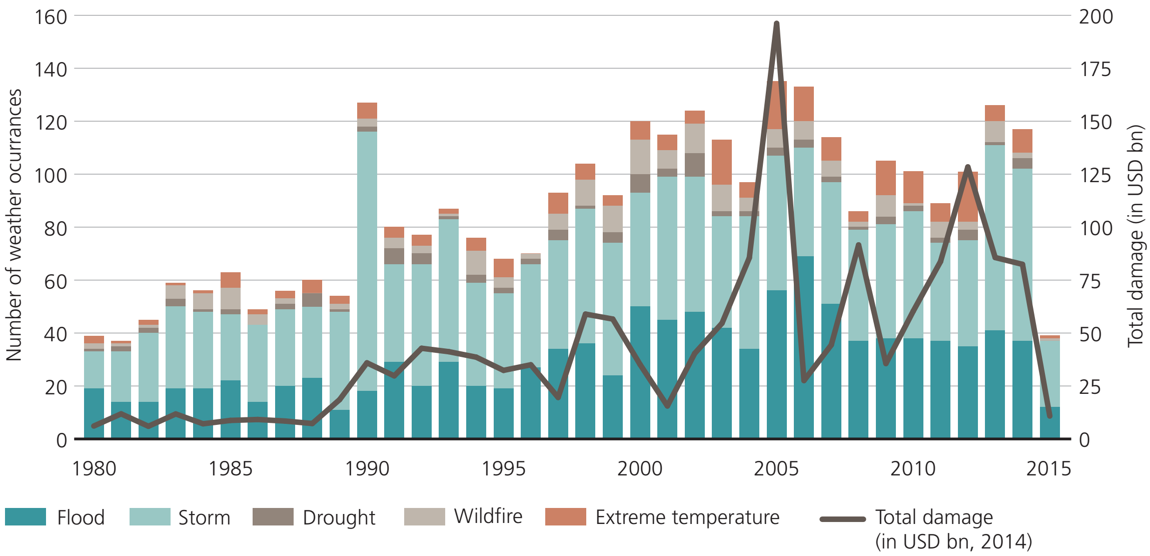
(Intergovernmental Panel on Climate Change, 2014)

Blooming Atacama desert in Chile. Photo by WIN-Initiative/Getty Images.

The Atacama Desert in Chile, known as the driest place on Earth, is experiencing an extremely rare bloom, spawned by heavy rains during a strong 2015 El Niño.[1] Farther north, extreme drought has led to another rare event this year: the 16th century Temple of Quechula in southern Mexico emerged from the receding waters of the Nezahualcoyotl reservoir.[2] And even farther north, the state of South Carolina was hit by a one in 1,000-year rainfall in October 2015, submerging nearly the entire state. While to the west, California is suffering through its fourth year of a historic drought, which is expected to cost the state USD 2.74 billion in 2015 due to agricultural losses.[3]

Across the world, the frequency of meteorological events (tropical storms, local storms) and associated flooding has increased since 1980. Notably, most of these events have occurred in Asia, where losses have been the largest, see Figures 1 and 2. Most fatalities have also been in Asia. North America is the next riskiest region, followed by Europe. In North America, most weather-related fatalities are associated with extreme heat (24%) and floods (21%), followed by tornadoes (16%), see Figure 3.

Figure 1: Weather Occurrence vs Economic Damage (USD bn, 2014) for UBS Country Sample



Source: EM-DAT, UBS analysis

Figure 2: 1980-2015 Extreme Weather Statistics by Region, UBS study sample

	Total occurrences	Total deaths	Total affected (million persons)	Total damage (scaled to USD bn, 2014)
Australia and New Zealand	214	1,131	16.14	44.26
Asia	3,146	586,264	5,476.85	702.12
Europe	1,273	146,286	35.56	277.88
Northern America	808	13,764	27.56	727.39
Central America	420	30,100	32.64	50.77
South America	584	45,491	134.07	44.29

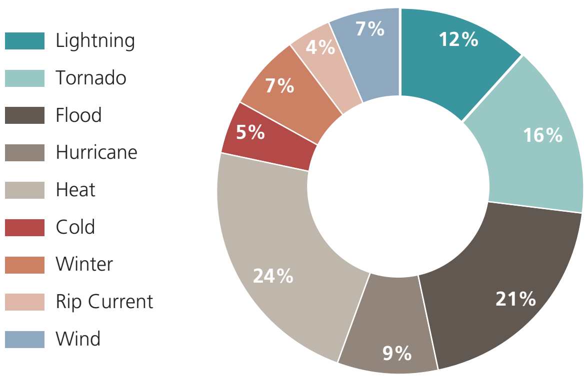
Source: EM-DAT, UBS analysis

Furthermore, we are learning about the interconnectedness of heavy precipitation events inland and warming of water bodies. For example, Black Sea warming has been linked to the 2012 devastating flash floods in Krymsk, which lies just inland of the Black Sea. Given current warmer Black Sea temperatures, researchers estimated a 300% increase in rainfall compared with the 1980s. Warmer waters destabilize the atmosphere and increase the likelihood of intense thunderstorms.[4] Similarly, the extreme floods in Pakistan can be linked to a high pressure system that settled over Moscow in the summer of 2010, triggering an extreme heatwave and pushing more summertime precipitation into Pakistan during monsoon season.[5] Here too, warm ocean temperatures played a role in shifting normal wind patterns (jet streams) and precipitation.

Globally, floods are the most costly natural disasters.[6] Cities in Southeast Asia are particularly exposed to extreme weather, threatening USD 12.6 trillion in GDP and close to a billion people. Floods in the US have on average caused USD 6 billion in property damages per year,[7] and have triggered nearly two-thirds of all presidential disaster declarations from 1950 to 2011.[8] Multiple countries have experienced severe and very costly floods in the past 10 years, including: China (2010), Morocco (2013; 2014), Pakistan (2010), Philippines (2012, 2013), Thailand (2010), Austria (2002, 2013), Australia (2011), France (2010), Germany (2013), the UK (2014) and the US (2005, 2008, 2012). In 2011, a record-breaking flood in Thailand caused insured losses of USD 15 billion and total economic damages of USD 46 billion.[9]

Global average sea level rose roughly eight inches from 1880 to 2009. And the speed at which it is rising is also increasing: From 1901 to 1990, the global average sea level rose by 1.2 mm per year. However, from 1990 to the present, global average sea level rose by 3.1 mm per year.[10] The US East Coast is emerging as particularly vulnerable to sea level rise.[11] Between 2009 and 2010, sea levels north of New York City jumped an unprecedented 128 mm. Simultaneously, the main current in the Atlantic Ocean, which carries hot tropical waters

Figure 3 : US natural disaster fatalities, 1995-2014



Source: NOAA, 2014

northward and cooler water south, slowed down by a dramatic 30% in just two years. The scientific community has been debating the possibility of shifts (a downturn and slow-down) in the Atlantic Ocean circulation due to Arctic Sea ice melt for quite some time. However, few expected to see evidence of such a sudden and dramatic shift in such a short time frame. Now the question is whether this is a one-off event or a recurring and increasing trend, with serious ramifications for climate patterns around the Atlantic basin.

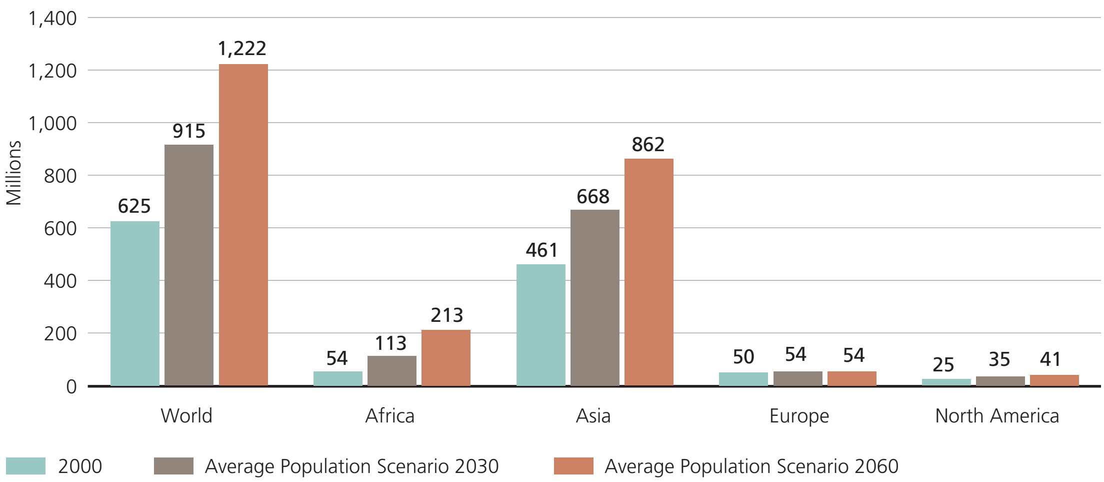
The New York City Panel on Climate Change noted that sea levels in New York City have risen by more than a foot (30.5 cm) since 1900.[12] The Union of Concerned Scientists analyzed 52 tide gauges along the US East and Gulf Coasts and found that many of the communities have experienced a fourfold increase in the annual number of days with tidal flooding since 1970.[13] By 2030, over 50% of East Coast communities are likely to experience an average of two dozen more tidal floods per year. Washington DC, Annapolis, Wilmington and Miami could very well be exposed to a tripling of high-tide floods per year. By 2045, many of these coastal communities are likely to face a one-foot sea level rise, and one-third may have to cope with tidal flooding more than 180 times a year on average (or 15 per month). In New York City, the sea level is expected to rise by an additional 11 to 21 inches by 2050.

A significant portion of the world's population lives in at-risk coastal areas that are below 10 meters above sea level.[14] On average, population density in these low-lying coastal zones is five times greater than the global average (241 people/km2 vs. 47 people/km2) and growing more rapidly than inland areas. Approximately 10.9% (625 million) of the 6.1 billion global population settled in these low-lying areas by 2000. Of these, 189 million lived in the 100-year flood plain. By 2030, 949 million people will live in low-lying coastal zones. By 2060, that same population may climb even more, reaching between 1 and 1.4 billion people (534 people/km2), or 12% of an estimated 11.3 billion global population. By 2030, between 268 million and 286 million people may be at risk from coastal flooding. By 2060, up to 411 million people (close to the entire 2015 US population) could be affected by extreme flooding events.

Populations at greatest flood risk are concentrated in Asia. In 2000, 73% of the total population living below 10 meters elevation resided in Asia, many of whom lived in flood-prone areas, see Figure 4. Under different population growth scenarios, that number may grow to 729 million or 983 million by 2060. Some of the densest and fastest-growing urban areas are in low-lying Chinese coastal zones, where growth has been three times the national rate. China is closely followed by India. Under a high-growth scenario, India could experience a threefold increase of its low elevation coastal zone (LECZ) population between the baseline year 2000 (64 million) and the year 2060 (216 million). The highest population growth to 2060 will be in low lying coastal zones in Bangladesh, India and Pakistan.

Europe and the Americas are relatively less exposed to flood risk, due in large part to lower expected population growth. In 2000, 50 million Europeans lived in low-lying coastal areas. Most of that risk is concentrated in Western Europe, where about 21 million people live in densely population low-lying coastal zones. Most reside in Netherlands (12 million or 73% of the population). The United Kingdom and Netherlands rank among the top 25 riskiest countries well into 2060. In 2000, only 24 million lived in low-lying coastal areas of North America. Of these, 23 million lived in the US, a figure that is expected to grow to 44 million by 2060. In Canada, only 1.6 million people are expected to be living below 10 m of elevation by 2060. In Brazil, 12 million people (6.6% of total population) were living in low-lying coastal areas (1.4% of the land area) in 2000. That number is expected to grow to 19 million by 2060.

Figure 4: Population living in low-lying coastal areas



Source: Neumann et al 2015

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