

December 2015

UBS Asset Management, Sustainable Investors Team

A revolution in equity investing

A deeper dive into nonfinancial data





Equity investing and security analysis are undergoing a paradigm shift toward a sharper focus on evaluating intangible assets. In parallel, sustainable investing is transforming from an investment approach heavily reliant on exclusionary screens and haunted by questions about underperformance, toward identifying outperforming companies using an extended mosaic of nonfinancial data. This advanced approach can reveal key insights that traditional equity analysts may overlook. In this paper, we describe the emergence of a globally standardized, objective approach to holistic security analysis along two dimensions: analyzing valuations from financial data, and incorporating nonfinancial (sustainable) data.

Key points

80% of the market value of S&P 500 firms is generated by intangible assets, including brand, reputation, R&D pipelines, customer satisfaction, health and safety record, environmental performance, and social license to operate, among others. In-depth analysis of material nonfinancial data is becoming more critical to assessing the contribution of these intangible assets to firm valuations. Sustainable investing is transforming into identifying outperforming companies through the analysis of an extended mosaic of data that incorporates material nonfinancial factors.

The global search for more comprehensive data

Today's (r)evolution in security analysis can best be understood in the broader context of how firms are valued today. Our understanding and analysis of a firm's economic value has changed meaningfully in the past 40 years. In 1975, 83% of a firm's market value was made up of tangible assets (see Exhibit 1). An equity analyst back then could safely rely on financial statements to estimate value. Today, the situation could not be more different. Indeed, it is the inverse: Only 16% of the market value of the S&P 500 firms is embedded in their tangible assets. The "remaining" 84% is associated with intangible assets. Identifying and valuing intangible assets, such as brand, reputation, culture, customer satisfaction, human capital, risk management, R&D and a company's social license to operate, are challenging because they rarely leave a clear imprint in financial statements. They require a fair amount of in-depth qualitative assessment and the application of new fields of academic and financial study, like assessing environmental risks, and evaluating societal externalities, both positive and negative. Today, there is clear evidence that the market considers these intangible assets to be extremely valuable. The challenge has been how to identify and measure nonfinancial factors in ways that are meaningful to equity analysts, and help them predict future business performance.

The search for nonfinancial data has parallels in the difficulty US equity analysts faced 20 years ago when looking for global financial data. Data for companies based in France or Singapore, for example, were not standardized and required extra effort to find, analyze and incorporate into investment decisions. But for analysts who rolled up their sleeves, the rewards were higher returns on an actively



Source: Ocean Tomo, January 2015

managed global equity portfolio. Since then, financial data have been standardized in the International Financial Reporting Standards (IFRS) set by the International Accounting Standards Board (IASB), yielding a more reliable and highly comparable data source on investment companies across the globe. Consequently, investors no longer question whether investing outside of the US is worthwhile. It's widely accepted today that our investible universe encompasses a global market where companies are influenced by globally interactive factors. This was a fundamental tenet of Gary Brinson's 'intrinsic value' investment philosophy when he founded one of our predecessor firms, and it remains the bedrock of the sustainable equity team's investment process today. Nonfinancial data are going through the same evolution and standardization process that has made global financial data so easy to access and use today. Over the past 15 years, the world's largest corporations have started to voluntarily disclose nonfinancial (sustainability) data on supply chain risks, health and safety records, and environmental pollution, in accordance with guidance from the Global Reporting Initiative (GRI). Today, the GRI lists over 400 indicators on corporate nonfinancial performance. In 2011, the Sustainability Accounting Standards Board (SASB) was launched to identify which environmental, social and governance (ESG) issues are most likely to be material for individual industry sectors. Going forward, the European Union has mandated disclosure of nonfinancial information as of 2017 for all public companies with over 500 employees.

Our central belief is that by considering this new and evolving set of nonfinancial data, equity analysts can deliver a more accurate and comprehensive view of a company's opportunities and risks. As equity investors, our job is to build the most complete mosaic of data possible to craft an informed opinion of a company's future growth prospects. For decades, we, like many investors, captured investment opportunities by identifying discrepancies between the price the market places on a security and estimates of long-term value. Today, by incorporating nonfinancial data into security analysis, we believe investors can paint a more accurate picture of a company's future profitability, identify risks to its value chain, and evaluate its ability to innovate and grow.

The materiality of sustainability data

It's not hard to grasp that 'nonfinancial' sustainability risks can have a real economic impact on companiessometimes of seismic proportions. When a clothing factory in Bangladesh collapsed in 2013, the negative ripple effects spread quickly across the international apparel industry. Mounting evidence that processed foods contribute to obesity, diabetes and digestive illnesses¹ is forcing a fundamental rethinking in the US food industry. Flooding in Thailand in 2011 caused significant disruptions in chip manufacturers' supply chains, erasing billions in forecasted revenues.² More recently, US national media are rife with reports of water mismanagement in drought-stricken California, after Governor Brown imposed a 25% reduction for urban water use this March. Many believe California's days as the supplier of almost half of US fruits and vegetables are numbered. According to the World Economic Forum's annual global risk rankings, water crises, failure to adapt to climate change, extreme weather events, and social instability/inequality have consistently ranked in the top five economic risks, and present a real challenge to corporate executives at global companies.³

Numerous studies have shown that information on environmental and social events (e.g., spills, accidents, fines and penalties, boycotts and labor strife) depress stock prices. In fact, research finds that from 1980 to 2009, stock prices dropped an average of 0.65 percent within the two-day window following the release of negative environmental news. For individual companies, these price drops can be quite dramatic. Environmental and social events can slash expected cash flows, and threaten the very survival of a business.⁴





Shareholders aren't the only actors driving companies to change. Edward Freedman posited that a broader coalition of 'stakeholders' is often the most effective change agent, comprised of employees, customers, suppliers, communities, government bodies, and a range of political and labor groups.⁵ These stakeholders typically target large companies in consumer products that are financially sound, but are heavy polluters. Stakeholders often repeatedly pressure an exposed company, especially if it has a strong brand and reputation.⁶ Once tainted, companies can become more susceptible to the negative effects of media attention and are more likely to accede to stakeholder demands, even if their sales have not been negatively affected and there is no material cash flow impact.⁷ In other words, a targeted company may be compelled to act (e.g., investing in pollution reduction or signing up to an environmental standard) to repair its reputation. When media get involved, the impact is amplified given how humans respond to bad news. A good rule of thumb is that one negative story is the equivalent of five positive stories.⁸ For example, stakeholder protests targeting labor (e.g., fair labor practices) or consumer issues (e.g., product safety or performance) with more media coverage tend to have a greater negative effect on stock returns than do boycotts alone.⁹ If an equity analyst believes that a company's economic value remains unimpaired by poor publicity, a price plunge may pose an attractive buying opportunity. Conversely, the disclosure of serious problems that leads to fines, sanctions or lost brand equity may cause real and long-lasting financial damage.

Controlling risks and creating value

No company and no technology is completely risk-free. Whether it is using a new technology, such as driving an electric car, making the car battery that contains heavy metals, or disposing of the toxic plastics in the car at the junk yard—each phase of a green car's "life-cycle" presents risks to human lives and to the ecosystem. Whether or how these risks are mitigated or exacerbated often depends on the actions or inactions of large corporate entities. For example, years ago the largest producer of chlorofluorocarbons (CFCs)-which destroy the Earth's protective ozone layer—was DuPont. Once the company agreed to end production of CFCs and shifted to a higher margin substitute of hydrofluorocarbons, governments had a better chance of agreeing to enact the Montreal Protocol in 1989, setting standards to protect the global ozone layer.¹⁰ Decades of scientific discovery have revealed



that many environmental and health risks are concentrated in a few industries. Coal-fired power, for example, is the biggest source of carbon emissions globally and a significant driver of climate change.¹¹ The (over)use of sugar in food products is closely tied to the global obesity epidemic.¹² And in the US, some of the most toxic and carcinogenic chemicals are largely emitted from just two industries: aluminum and cement.¹³

The take-home from these examples of environmental and health issues is that they can pose a real economic threat to corporations in various industries, jeopardizing the value corporate executives seek to deliver to their shareholders. While some of these risks can be controlled, others (e.g., climate change and demands from customers and local communities) are far more difficult for corporate executives to manage (see Exhibit 2). However, when the evidence of an ESG risk begins to mount, it behooves a company to act and to do so ahead of the issue, and more importantly, ahead of the competition. Smart companies can be strategic in how they mitigate risks. By using a forward-looking strategy that embraces a consistent set of actions, corporate leadership can ensure "that the competitive advantages of activities cumulate and do not erode or cancel themselves out."¹⁴ For example, corporate management can alter product design or production methods to minimize operational and technology risks. However, risks associated with a company's global supply chain may be harder to manage because they are not directly owned.





Source: Adapted from "Re-Imagine Risk and Value—Profit from What Counts Today," Deloitte, The Risk Series, 2014.

Some supply chain risks can actually represent an opportunity and not just a liability, given shareholder and community stakeholder demands. For example, while some apparel companies dropped suppliers that employed child labor, others partnered with their suppliers to keep children in school. This is one of many examples where companies successfully built shared value within their nearby communities. Consideration of these risks (and opportunities) can help a company compete within its industry, creating value not only for its shareholders, but also value for its broader community. Conversely, corporate executives who ignore tangible risks can create uncertainties that eventually threaten cash flows, and drive stock prices down.

Many strategies that corporations use to minimize risks, such as reducing material inputs like water and energy, are consistent with profitable management practices because they lower costs and improve margins (see Exhibit 3). Similarly, in today's asset-light, knowledge-intensive companies in Silicon Valley, creating an environment that attracts and keeps talented employees is not a luxury; it is an essential component of a highly competitive business strategy. Safe and efficient factories lower insurance costs, create superior working environments and produce higher-quality products that are well-perceived by consumers.

Analyzing risks and values holistically

Clearly, a company is more than just the sum of its parts and its balance sheet. As Michael Porter, a leading scholar of competitive strategy, noted back in 1981,¹⁵ the operating environment of a company is highly complex (see Exhibit 4 on the following page). Effectively analyzing a company's future growth prospects requires an equity analyst to consider



Exhibit 3: Effective company management

Source: "Creating Shared Value," Michael E. Porter and Mark R. Kramer, Harvard Business Review, Jan–Feb 2011.

not only a company's strengths and weaknesses, and external industry and technological threats, but also its corporate executives' values and behaviors, and constraints imposed by broader societal expectations. Porter proposed that the goals of a company should encompass both "economic and noneconomic considerations," such as social obligations, treatment of employees, and the company's overall organ-izational climate. Equity analysts and investors ignore this complexity at their own risk.



Exhibit 4: Analyzing sources of value and risks Company strengths/weaknesses External industry/ technological threats Corporate executives' Values & behaviors Constraints via broad societal expectations

Source: Michael Porter, "The Contributions of Industrial Organization to Strategic Management," *The Academy of Management Review*, October 1981, Vol. 6, No. 4, pp. 609–620.

Research on gold mines helps us understand how a proactive response to what Porter termed "societal expectations" can impact security valuations. It turns out that gold mines with a track record of positive engagement with local community stakeholders enjoy a significantly lower cash flow discount rate at 12% than those with contentious relations (72% discount rate). Why? Regulators and local community activists can inflict crippling production delays if a mine operator ignores them. It turns out that the value of positive relationships was worth twice as much as the gold controlled by the mines.¹⁶

Nonfinancial indicators of success are not obvious, and quite hard to find in financial statements. That is precisely why they can be a differentiator for active investment managers that know how to identify and measure them. Many are fundamental factors that help illuminate whether company executives are managing their assets smartly both tangible and intangible (e.g., physical, intellectual and reputational)—and driving shareholder value upwards. Rather than detracting from returns, security analysis that incorporates nonfinancial sustainability factors and a broader mosaic of data helps equity analysts identify truly competitive business models and companies that can generate attractive financial results. *****

Footnotes

- ¹ http://www.hsph.harvard.edu/nutritionsource/sugary-drinks-fact-sheet/; http://www.hsph.harvard.edu/nutritionsource/healthy-drinks/soft-drinks-and-disease/; http://www.lfpress.com/2015/03/08/autisms-bacteria-link-gains-credence.
- ² The New York Times, December 14, 2011, reported that Intel announced that its fourth-quarter revenue would be \$13.4 billion to \$14 billion, down from a previous forecast of \$14.2 billion to \$15.2 billion because of supply shortages of hard disk drives, as a result of flood damage to factories in Thailand. Shares of Intel lost 4% to close at \$24.
- ³ WEF Global Risks 2015 Report, January 2015.
- ⁴ Dinah A. Koehler and Eric J. Hespenheide, "Finding the value in environmental, social and governance performance," Deloitte University Press, 2013; Caroline Flammer, "Corporate Social Responsibility and Shareholder Reaction: The Environmental Awareness of Investors," *Academy of Management Journal*, 2013, 56 (3), pp. 758–781. From 1980 to 1990, the average abnormal return associated with negative environmental news was -0.42%, increased to -0.66% during 1990–2000, and increased further to -1.12% during 2000–2009.
- ⁵ R. Edward Freeman, Strategic Management: A stakeholder approach, Boston: Pitman, 1984.
- ⁶ Michael E. Conroy, "Branded: How the 'certification revolution' is transforming global corporations," New Society Publishers, 2007; Michael Lenox and Charles Easley, "Private environmental activism and the selection and response of firm targets," *Journal of Economics Management and Strategy*, 2009, p.18, no. 1; Sam Gupta and Robert Innes, "Determinants and environmental impact of private politics: An empirical analysis," University of Arizona, 2009.
- ⁷ Brayden G. King, "A political mediation model of corporate response to social movement activism," Administrative Science Quarterly, 2008, p.53.
- ⁸ Roy F. Baumeister et al., "Bad is stronger than good," *Review of General Psychology* 5, 2001, no. 4; Paul Rozin and Edward D. Royzman, "Negativity bias, negativity dominance, and contagion," *Personality and Social Psychology Review* 5, 2001, no. 4.
- ⁹ Brayden G. King and Sarah A. Soule, "Social movements as extra-institutional entrepreneurs: The effect of protests on stock price returns," *Administrative Science Quarterly*, 2007, p. 52.
- ¹⁰ https://eng.ucmerced.edu/people/awesterling/copy_of_ESS141.2010/Assignments/DuPont.
- ¹¹ Trends in Global CO₂ Emissions Report, 2014; PBL Netherlands Environmental Assessment Agency.
- ¹² http://www.hsph.harvard.edu/nutritionsource/sugary-drinks-fact-sheet.
- ¹³ Dinah A. Koehler, Deborah H. Bennett, Gregory A. Norris, and John D. Spengler, "Rethinking Environmental Performance from a Public Health Perspective—A Comparative Industry Analysis," *Journal of Industrial Ecology*, 2005, Volume 9, Number 3, pp. 143–167.
- ¹⁴ Michael Porter, "What is strategy," Harvard Business Review, November–December 1996, pp. 61–78.
- ¹⁵ Michael Porter, "The Contributions of Industrial Organization to Strategic Management," The Academy of Management Review, October 1981, Vol. 6, No. 4, pp. 609–620.
- ¹⁶ Witold J. Henisz, Sinziana Dorobantu and Lite J. Nartey, "Spinning gold: The financial returns to stakeholder engagement," *Strategic Management Journal*, 2013, Vol 35:12, pp. 1727–1748.

Sustainable Equity Team

Bruno Bertocci

Chicago

Team Head, Senior Portfolio Manager

Years experience: 34 Years with UBS: 16

Oberlin College, AB Harvard Business School, MBA

Joe Elegante Chicago

Senior Portfolio Manager

Years experience: 22 Years with UBS: <1

Miami University, BS Case Western Reserve University, MBA

Jay Eisenhardt Chicago

Portfolio Manager

Years experience: 11 Years with UBS: 11

University of Missouri, Columbia BS, BA University of Chicago, MBA

Shari Gilfillan Chicago

Equity Specialist

Years experience: 21 Years with UBS: 18

Miami University, BS DePaul University, MBA **Dinah A. Koehler** New York

Equity Specialist

Years experience: 21 Years with UBS: <1

Wellesley College, BA Tufts University, MA Harvard University, ScD

What sets UBS Asset Management apart

Your global investment challenges answered

An increasingly complex and interconnected world presents investors with many questions, and answers can be hard to find. Drawing on the breadth and depth of our capabilities and our global reach, we turn challenges into opportunities. Together with you, we find the solution that you need.

Leading institutional asset manager

UBS Asset Management, a business division of UBS, is a large-scale asset manager with well-diversified businesses across regions, capabilities, and client segments. Whatever your investment profile or time horizon, we offer a comprehensive range of active and passive investment styles and strategies designed to meet your needs across traditional and alternative asset classes. Our invested assets total USD 652 billion¹ and we have over 2,400 employees in 24 countries.

¹As of September 30, 2015. UBS Asset Management (Americas) Inc. is a member of UBS Asset Management, and has USD 148 billion in assets under management as of September 30, 2015.

Disclosure

The views expressed are as of September 30, 2015 and are a general guide to the views of UBS Asset Management. This document does not replace portfolio and fund-specific materials. Commentary is at a macro or strategy level and is not with reference to any registered or other mutual fund. This document is intended for limited distribution to the clients and associates of UBS Asset Management. Use or distribution by any other person is prohibited. Copying any part of this publication without the written permission of UBS Asset Management is prohibited. Care has been taken to ensure the accuracy of its content but no responsibility is accepted for any errors or omissions herein.

Please note that past performance is not a guide to the future. Potential for profit is accompanied by the possibility of loss. The value of investments and the income from them may go down as well as up and investors may not get back the original amount invested.

This document is a marketing communication. Any market or investment views expressed are not intended to be investment research. The document has not been prepared in line with the requirements of any jurisdiction designed to promote the independence of investment research and is not subject to any prohibition on dealing ahead of the dissemination of investment research.

The information contained in this document does not constitute a distribution, nor should it be considered a recommendation to purchase or sell any particular security or fund. The information and opinions contained in this document have been compiled or arrived at based upon information obtained from sources believed to be reliable and in good faith. All such information and opinions are subject to change without notice.

A number of the comments in this document are based on current expectations and are considered "forward-looking statements." Actual future results, however, may prove to be different from expectations. The opinions expressed are a reflection of UBS Asset Management's best judgment at the time this document is compiled and any obligation to update or alter forward-looking statements as a result of new information, future events, or otherwise is disclaimed. Furthermore, these views are not intended to predict or guarantee the future performance of any individual security, asset class or market generally, nor are they intended to predict the future performance of any UBS Asset Management account, portfolio or fund.

Services to US clients for any strategy herein are provided by UBS Asset Management (Americas) Inc. ("Americas"). Americas is registered as an investment adviser with the US Securities and Exchange Commission ("SEC") under the Investment Advisers Act of 1940.

Indices referenced herein are not available for direct investment. For a detailed description of the indices referenced and further definitions of terms, please visit:

http://www.ubs.com/us/en/asset_management/individual_investors/mutual_fund.html



Climate change: A risk to the global middle class

Exposure, vulnerability & economic impact

A UBS and Society Report



Publication details

This report was published on January 11, 2016.

Editor-in-chief and lead author Dr. Dinah A. Koehler

Contributing authors

(in alphabetical order) Bruno Bertocci Dr. Jonathan J. Buonocore Paul Donovan Andi Gordon Dr. Howard Kunreuther

Project Management Tara Giuliano

Cover photo gettyimages/Jasper James

Contents

Climate change: A risk to the global middle class

04**Executive summary** 08 Chapter 1 – 2015: Another exceptional year 13 Chapter 2 – Middle-class exposure: Locating and characterizing the global middle class 21 Chapter 3 - Vulnerability: How is the middle class affected and can they adapt? 33 **Country spotlight: Australia** 35 Chapter 4 - Strategies for dealing with climate change risks: Behavioral issues and affordability challenges 41 Conclusion 43 Appendices

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, middleclass 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 adaptingeven 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.

- 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."

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

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.

⁵ United Nations, Department of Economic and Social Affairs, Population Division (2013). World Population Ageing 2013. ST/ESA/ SER.A/348.

⁶ Robine et al, "Death toll exceeded 70 000 in Europe during the summer of 2003," Comptes Rendus Biologies 331, no. 2 (2008): 171–8.

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).

¹⁰ Maximilian Auffhammer, "Explaining the Adoption of Air Conditioners in China's Urban and Rural Households," UC Berkeley for the US EPA Oct. 12, 2011.

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 &}quot;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.

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.





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 combustioncoal-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.

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-elnino-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-ninofueling-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/capital-weather-gang/wp/2015/10/20/el-ninofueling-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/energyenvironment/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_201511101&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/europerefugee-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 Framework¹ (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 guickly 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 lowerincome 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.

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	Токуо	С	500,336.81	52%	61%	0.70%	3.9%	1
2	New York	С	312,156.44	29%	52%	0.10%	2.4%	1
3	Osaka	С	236,520.24	51%	58%	0.60%	2.4%	1
4	Los Angeles	С	200,352.38	35%	58%	0.10%	2.3%	1
5	Chicago	1	164,368.35	37%	58%	0.70%	2.1%	1
6	Dallas	1	120,413.45	40%	61%	0.80%	3.9%	1
7	Таіреі	С	116,951.89	47%	62%	2.90%	0.9%	1
8	Houston	С	107,643.79	38%	60%	1.60%	3.6%	2
9	Nagoya	С	105,537.33	44%	57%	1.00%	2.5%	1
10	Philadelphia	С	105,518.26	36%	57%	-0.50%	1.9%	1
11	Miami	С	103,552.05	43%	62%	-0.50%	1.9%	1
12	London	С	103,467.79	20%	34%	2.50%	1.6%	1
13	Shanghai	С	96,866.97	21%	31%	5.20%	8.3%	1
14	São Paulo	1	95,933.25	31%	49%	-1.50%	5.7%	1
15	Atlanta	1	95,812.13	40%	61%	1.50%	4.1%	2
16	Beijing	1	93,700.51	25%	34%	4.70%	7.4%	2
17	Washington	С	92,181.87	23%	47%	-1.50%	3.1%	2
18	Phoenix	1	81,918.62	45%	64%	0.70%	2.5%	2
19	Boston	С	79,243.84	29%	52%	0.50%	2.1%	1
20	Detroit	I	77,819.17	45%	61%	0.80%	2.3%	1

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

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 temperaturerelated 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 heatrelated 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

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	Таіреі
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

Figure 6: Top 20 city hazard rankings

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

Middle class exposure: Locating and characterizing the global middle class

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_wgIl_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 countrya 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 heatrelated mortality, and vice versa. We assessed the cities according to the worst-case scenario and found 62 cities that ranked in the topquartile 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



Relative middle class household spending ex London and Miami



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





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 middleclass 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 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	
â	Spain	512	1,025	
*	Australia	604	1,209	
*	Taiwan	657	1,315	
	United States	795	1,590	

Source: UBS analysis

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.

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 disposableincome 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 middleclass 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 middleclass 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 guite 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

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%

Figure 12: Country adaptation overview

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



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

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

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).

² Swiss Re, "Underinsurance of property risks: closing the gap," Sigma report, no. 5 (2015).

³ Ibid.

⁴ Ibid.

⁵ Ibid.

⁶ Ibid.

^{7 &}quot;Improved Criteria Needed to Assess a Jurisdiction's Capability to Respond and Recover on Its Own," U.S. Government Accountability Office, GAO-12-838, September 12, 2012.

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

⁹ Carolyn Kousky, Erwann O. Michel-Kerjan, and Paul A. Raschky, "Does Federal Disaster Assistance Crowd out private demand for insurance?," (working paper, Wharton School, University of Pennsylvania, October 2013).

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, waterlogging 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.

¹ Credit Suisse, "The Global Wealth Report 2015," 2015.

² Will Steffen, "Quantifying the impact of climate change on extreme heat in Australia," Climate Council, 2015.

³ "State of the Climate 2014," Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology, Melbourne.

⁴ Will Steffen, "Thirsty County: Climate change and drought in Australia," Climate Council, 2015; "Climate change challenges to health: Risks and opportunities," Australian Academy of Sciences, 2014.

⁵ I.C. Hanigan et al, "Suicide and Drought in New South Wales, Australia, 1970-2007," Proceedings of the National Academy of Sciences, 13950-395 (2012).

⁶ G. Horton, L. Hanna and B. Kelly, "Drought, Drying and Climate Change: Emerging Health Issues for Ageing Australians in Rural Areas," Australasian Journal on Ageing 29 (2010): 2–7.

^{7 &}quot;Climate Adaptation Outlook: A proposed national adaptation assessment framework," Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, 2013.

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 largescale 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 hazardprone 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 riskbased 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 riskbased 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 costeffective 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. Strategies for dealing with climate change risks: Behavioral issues and affordability challenges

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.

4 Daniel Kahneman, Thinking, fast and slow (New York: Farrar, Straus and Giroux, 2013).

^{1 &}quot;Catastrophes: Insurance Issues," Insurance Information Institute, December 2015, http://www.iii.org/issue-update/ catastrophes-insurance-issues.

² Kunreuther, H. (2015) "The Role of Insurance in Reducing Losses from Extreme Events: The Need for Public–Private Partnerships" The Geneva Papers, 40:741–762.

³ Mei et al, "Northwestern Pacific typhoon intensity controlled by changes in ocean temperatures" Science Advances 1, (4) (2015).

⁵ D.M. Cutler and R.J. Zeckhauser "Extending the Theory to Meet the Practice of Insurance," edited by Robert Litan and Richard Herring, Brookings-Wharton Papers on Financial Services, 2004. Washington DC: Brookings Institution; D. Krantz and H. Kunreuther, "Goals and plans in decision-making" Judgment and Decision Making 2 (2007):137-68; H. Kunreuther, M.V. Pauly and S. McMorrow, Insurance and Behavioral Economics: Improving Decisions in the Most Misunderstood Industry (New York: Cambridge University Press, 2013).

⁶ A. Tversky and D. Kahneman, "Availability: A heuristic for judging frequency and probability," Cognitive Psychology 5 (2) (1973): 207-232.

⁷ W. Botzen, H. Kunreuther and E. Michel-Kerjan "Divergence between Individual Perceptions and Objective Indicators of Tail Risks: Evidence from Floodplain Residents in New York City," Judgment and Decision Making, 10 (2015): 365-85.

⁸ H. Kunreuther and E. Michel-Kerjan "Demand for Fixed-Price Multi-Year Contracts: Experimental Evidence from Insurance Decisions," Journal of Risk and Uncertainty 51(2) (2015).

⁹ E. Michel-Kerjan, S. Lemoyne de Forges and H. Kunreuther, "Policy tenure under the U.S. National Flood Insurance Program (NFIP), Risk Anal 32 (4) (2012):644-58.

¹⁰ R. Thaler and C. Sunstein, Nudge: The gentle power of choice architecture (New Haven, CT: Yale University, 2008); Johnson et al, "Beyond nudges: Tools of a choice architecture," *Marketing Letters* (2012): 1-18.

¹¹ H. Kunreuther, N. Novemsky and D. Kahneman, "Making Low Probabilities Useful," *Journal of Risk and Uncertainty* 23 (2001): 103-120.

¹² National Research Council (2015a). Affordability of National Flood Insurance Program Premiums—Report 1. Washington, D.C.: The National Academies Press.

¹³ The Benefits of Modern Wind Resistant Building Codes on Hurricane Claim Frequency and Severity—A Summary Report, Institute for Business & Home Safety (IBHS), 2007.

¹⁴ Kunreuther and Michel-Kerjan, 2015.

¹⁵ A. Atreya et al, "A Comparison of Residential Flood Insurance Markets in 25 Countries," (working draft, Wharton-IIASA-Zurich).

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 topranked 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 presentday 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 guartile 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 temperaturesof 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.

^{1 &}quot;The Global Risks 2015 Report," World Economic Forum, Infographic. Available at: http://reports.weforum.org/global-risks-2015/ top-10-infographics/.

² Kelley et al, "Climate change in the Fertile Crescent and implications of the recent Syrian drought," Proceedings of the National Academy of Sciences 122, (11) (2015): 3241-3246.

³ Bruce Stokes, Richard Wike and Jill Carle, "Global Concern about Climate Change, Broad Support for Limiting Emissions," Washington, D.C.: Pew Research Center, http://www.pewglobal.org/2015/11/05/ global-concern-about-climate-change-broad-support-for-limiting-emissions/.

⁴ Nikhil Kumar, "India's Need for Coal-Powered Growth Complicates Paris Climate Summit," Time, December 1, 2015.

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.

Dr. Jonathan Buonocore and Andi Gordon, Harvard School of Public Health

_			
		-	
	111		

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 CO₂ emissions (from fossil fuel combustion for electricity).7 Metropolitan areas are also often burdened by air pollution, which increases mortality. Emissions

······································							
Start	End	Country	Total				
Date	Date	Name	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				

Figure 1: Extreme heat events and mortality

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,





Source: S. Hajat et al, 2014



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,



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





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.

- 1 Guha-Sapir et al, "EM-DAT: International Disaster Database," Université Catholique de Louvain, Brussels, Belgium, www.emdat.be.
- ² Huynen et al, "The Impact of heat waves and cold spells on mortality rates in the Dutch population," *Environmental Health Perspectives* 109 (2001):463–470.
- ³ M. Medina-Ramón and J. Schwartz, "Temperature, temperature extremes, and mortality: a study of acclimatisation and effect modification in 50 US cities," *Occupational and Environmental Medicine* 64(12) (2007): 827–33; F. Curriero et al, "Temperature and mortality in 11cities of the eastern United States," *Am J Epidemiology* 155(1) (2002): 80–87; Ye et al, "Ambient temperature and morbidity: A review of epidemiological evidence," *Environmental Health Perspectives* 120(1) (2012): 19–28; Berko et al, "Deaths Attributed to Heat, Cold, and Other Weather Events in the United States, 2006–2010," *National Health Statistics Reports* 76(30) (2014): 1-15; J. Schwartz, "Who is Sensitive to Extremes of Temperature?" *Epidemiology* 16(1) (2005): 67–72; Åström et al, "The effect of heat waves on mortality in susceptible groups: a cohort study of a Mediterranean and a northern European City," Environmental Health: A Global Access Science Source 14(1) (2015): 30; Gao et al, "Impact of extreme high temperature on mortality and regional level definition of heat wave: a multi-city study in China," *The Science of the Total Environment* 505 (2015): 535–44; A. Gasparrini and B. Armstrong, UKPMC Funders Group, "The impact of heat waves on mortality," *Epidemiology* 22(1) (2012): 68–73. Vardoulakis et al, "Comparative Assessment of the Effects of Climate Change on Heat- and Cold-Related Mortality in the United Kingdom and Australia," *Environmental Health Perspectives* 122(12) (2014): 1285–1293.
- ⁴ Guirguis et al, "The Impact of Recent Heat Waves on Human Health in California," *Journal of Applied Meteorology and Climatology* 53(1) (2013): 3–19.
- ⁵ United Nations, Department of Economic and Social Affairs, Population Division (2013). *World Population Ageing* 2013. ST/ESA/ SER.A/348; Bloom et al, "Implications of population ageing for economic growth. *Oxford Review of Economic Policy* 26(4) (2010): 583–612.
- 6 J. Schwartz (2005); WHO (2012). Global status report on non-communicable diseases 2014. Geneva, World Health Organization, 2012; Sarah Wild, "Global Prevalence of Diabetes," *Diabetes Care* 27 (5) (2004): 1047-1053.
- PEPA. Heat Island Effect. U.S. Environmental Protection Agency; 2005. Available at: http://www.epa.gov/heatisland/about/index.html; Q. Huang and Y. Lu, "The Effect of Urban Heat Island on Climate Warming in the Yangtze River Delta Urban Agglomeration in China," *International Journal of Environmental Research and Public Health* 12(8) (2015): 8773–8789; Zhang et al, "Temporal and spatial characteristics of the urban heat island during rapid urbanization in Shanghai, China," *Environmental Monitoring and Assessment* 169 (2010): 101–112; Tan et al, "The urban heat island and its impact on heat waves and human health in Shanghai," *International Journal of Biometeorology* 54(1) (2010): 75–84; M. S. O'Neill, "Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence," *Journal of Urban Health: Bulletin of the New York Academy of Medicine* 82(2) (2005): 191–197; C. de Munck et al, "How much can air conditioning increase air temperatures for a city like Paris, France?" *International Journal of Climatology* 33(1) (2013): 210–227; Dousset et al, "Satellite monitoring of summer heat waves in the Paris metropolitan area," *International Journal of Climatology* 31(2) (2011): 313–323.
- ⁸ C. Pope III and D. Dockery, "Health Effects of Fine Particulate Air Pollution : Lines that Connect," Air & Waste Manage. Association 56(6) (2006), 709–742; Dockery et al, "An Association between Air Pollution and Mortality in Six U.S. Cities," New England Journal of Medicine 329(24) (1993): 1753–1759; Analitis et al, "Effects of Heat Waves on Mortality," Epidemiology 25(1) (2014): 15–22; Quinn et al, "Predicting indoor heat exposure risk during extreme heat events," Science of The Total Environment 490(15) (2014): 686–693.
- 9 E. Klinenberg, Heat wave : a social autopsy of disaster in Chicago (Chicago; London: Univ. of Chicago Press, 2002)
- ¹⁰ Poumadère et al, "The 2003 Heat Wave in France: Dangerous Climate Change Here and Now," *Risk Analysis* 25(6) (2005): 1483–1494; Fouillet et al, "Has the impact of heat waves on mortality changed in France since the European heat wave of summer 2003? A study of the 2006 heat wave," *International Journal of Epidemiology* 37(2) (2008): 309–317.
- 11 Michelozzi et al, "The impact of the summer 2003 heat waves on mortality in four Italian cities," Euro Surveill 10(7) (2005):pii=556.
- ¹² Semenza et al, "Heat-related deaths during the July 1995 heat wave in Chicago," *The New England Journal of Medicine* 335(2) (1996): 84–90.
- G. Havenith, "Temperature regulation, Heat balance and climatic stress," Extreme Weather Events and Public Health Responses (2005) 69–80; A. Bouchama and J. Knochel, "Heat Stroke," New England Journal of Medicine 346(25) (2002): 1978–1988.
- 14 NOAA. "The Global Surface Temperature is Rising." National Centers for Environmental Information. Global Climate Change Indicators – Warming Climate. https://www.ncdc.noaa.gov/indicators/. Retrieved 11/04/15.
- ¹⁵ Lorenzo et al, "Heat acclimation improves exercise performance," Journal of Applied Physiology 109(4) (2010): 1140–1147; S. C. Sherwood and M. Huber, "An adaptability limit to climate change due to heat stress," Proceedings of the National Academy of Sciences 107(21) (2010): 9552–9555; Shi et al, "Impacts of temperature and its variability on mortality in New England," *Nature Climate Change* (July) (2015), 1–5.
- ¹⁶ Zanobetti et al, "Summer temperature variability and long-term survival among elderly people with chronic disease," *Proceedings of the National Academy of Sciences* 109(17) (2012): 6608–6613; C. Schär et al, "The role of increasing temperature variability for European summer heat waves," *Nature* 427 (2004): 332-336.
- 17 Coumou et al, "Global increase in record-breaking monthly-mean temperatures," Climatic Change 118(3-4) (2013): 771–782.
- ¹⁸ Gasparrini and Armstrong, 2012; Braga et al, "The Time Course of Weather-Related Deaths," *Epidemiology* 12(6) (2001): 662-667; R. S. Kovats and S. Hajat, "Heat Stress and Public Health: A Critical Review," Annual Review of Public Health 29(1) (2008): 41–55; Gosling et al, "Associations between elevated atmospheric temperature and human mortality: a critical review of the literature," Climatic Change 92 (3-4)(2009): 299-341; Nordio et al, "Changing patterns of the temperature–mortality association by time and location in the US, and implications for climate change," Environment International 81 (2015): 80–86; Medina-Ramón et al, "Extreme temperatures and mortality: Assessing effect modification by personal characteristics and specific cause of death in a multi-city case-only analysis," Environmental Health Perspectives 114(9) (2006): 1331–1336; Gasparrini et al, "Mortality risk attributable to high and low ambient temperature: a multicountry observational study," *The Lancet* 6736(14) (2015): 1–7.
- ¹⁹ B. Anderson and M. Bell, "Heat waves in the United States: Mortality risk during heat waves and effect modification by heat wave characteristics in 43 U.S. communities," *Environmental Health Perspectives* 119(2) (2011): 210–218.
- ²⁰ Hansen et al, "Perception of climate change," Proceedings of the National Academy of Sciences 109(37) (2012): E2415–E2423.
- 21 G. Meehl, "More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century," *Science* 305(5686) (2004): 994–997; Christensen et al, "European and Global Climate Change Projections: Discussion of Climate Change Model Outputs, Scenarios and Uncertainty in the EC RTD Climate Cost Project," The Climate Cost Project. Final Report. Volume 1: Europe (2011).

- 22 N. Wiltgen, "Northwest Heat Wave By the Numbers: Dozens of Monthly and All-Time Record Highs," The Weather Channel, (2015); J. Erdman, "Heat Records Shattered in Germany, France, The Netherlands in June/July 2015 Europe Heat Wave," The Weather Channel, (2015). www.weatherchannel.com.
- 23 Barriopedro et al," The Hot Summer of 2010 : Map of Europe," (April, 2011), 220-224.
- 24 J. S. Pal and E. Eltahir, "Future temperature in southwest Asia projected to exceed a threshold for human adaptability," *Nature Climate Change* (2015); Sherwood and Huber, 2010.
- ²⁵ Murari et al, "Intensification of future severe heat waves in India and their effect on heat stress and mortality," *Regional Environmental Change* 15 (4) (2015): 569.
- ²⁶ Hayhoe et al, "Emissions pathways, climate change, and impacts on California," *Proceedings of the National Academy of Sciences* 101(34) (2004): 12422–7; Baccini et al, "Impact of heat on mortality in 15 European cities: attributable deaths under different weather scenarios," *Journal of Epidemiology and Community Health* 65 (2011): 64–70; Hajat et al, "Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s and 2080s," *Journal of Epidemiology & Community Health* 68(7) (2014): 641–648; Takahashi et al, "Assessing Mortality Risk from Heat Stress due to Global Warming," *Journal of Risk Research* 10(3) (2007), 339–354.
- ²⁷ Fouillet et al, "Has the impact of heat waves on mortality changed in France since the European heat wave of summer 2003? A study of the 2006 heat wave," *International Journal of Epidemiology* 37(2) (2008): 309–317; Fouillet et al, "Excess mortality related to the August 2003 heat wave in France," *International Archives of Occupational and Environmental Health* 80(1) (2006), 16–24.
- ²⁸ Barreca et al, "Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the 20th Century," NBER Working Paper, (January 2013), 46; M. Auffhammer and E.T. Mansur, "Measuring climatic impacts on energy consumption: A review of the empirical literature," *Energy Economics* 46 (2014): 1–28.
- ²⁹ L. W. Davis and P. J. Gertler, "Contribution of air conditioning adoption to future energy use under global warming," *Proceedings of the National Academy of Sciences* 112, no.19 (2015): 5962–5967; original source: Euromonitor International (2014) Air Treatment Products in China (Euromonitor International, Shanghai, China).
- ³⁰ E. Gupta, "Global warming and electricity demand in the rapidly growing city of Delhi: A semi-parametric variable coefficient approach," *Energy Economics* 34(5) (2012): 1407–1421.
- ³¹ Davis and Gertler, 2015.
- ³² Auffhammer and Mansur, 2014.
- 33 A. Chrisafis, "Weather alerts across western Europe as heatwave sets in," (2015). http://www.theguardian.com/world/2015/jul/01.
- 34 Miller et al, "Climate, Extreme Heat, and Electricity Demand in California," Journal of Applied Meteorology and Climatology 47(6) (2008): 1834–1844.
- ³⁵ S. Aivalioti, "Electricity Sector Adaptation to Heat Waves," Columbia University Academic Commons, 2015, http://dx.doi.org/10.7916/ D8D799MC.
- ³⁶ Department of Energy (DOE). U.S. energy sector vulnerabilities to climate change and extreme weather. Washington, DC, 2013.
- ³⁷ M. Davis and S. Clemmer, "Power Failure How Climate Change Puts Our Electricity at Risk and What We Can Do," Union of Concerned Scientists, 2014.
- ³⁸ Parry et al, "Effects of climate change on global food production under SRES emissions and socio-economic scenarios," *Global Environmental Change* 14(1) (2004): 53–67: D.S. Battisti and R.L. Naylor, "Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat," *Science* 323(5911) (2009): 240–244; Raleigh et al, "The devil is in the details: An investigation of the relationships between conflict, food price and climate across Africa," *Global Environmental Change* 32 (2015): 187–199.

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.





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 floodprone 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.



Source: Neumann et al 2015

9 Swiss Re, "Mind the Risk," 2014; Swiss Re, Sigma 2015.

¹ Angela Fritz, "The 'driest place on Earth' is covered in pink flowers after a crazy year of rain, "The Washington Post, October 29, 2015, https://www.washingtonpost.com/news/capital-weather-gang/wp/2015/10/29/ the-driest-place-on-earth-is-covered-in-pink-flowers-after-a-crazy-year-of-rain/?wpmm=1&wpisrc=nl_headlines.

² David Leveille, "A 16th century church and its bloody history re-emerge from a lake in southern Mexico," *PRI's The World*, October 20, 2015, http://www.pri.org/stories/2015-10-20/16th-century-church-and-its-dark-history-re-emerge-lake-southern-mexico.

³ "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.

⁴ Meredith et al, "Crucial role of Black Sea Warming in amplifying the 2012 Krymsk precipitation extreme," Nature Geoscience 8, (2015): 615-619.

⁵ Jeff Masters, "Causes of the Russian heat wave and Pakistani floods," August 13, 2010, Weather Underground (blog) http://www. wunderground.com/blog/JeffMasters/comment.html?entrynum=1576.

⁶ S. Miller, R. Muir-Wood and A. Boissonnade, "An Exploration of Trends in Normalized Weather-Related Catastrophe Losses. In Climate Extremes and Society," edited by H. F. Diaz and R. J. Murnane, (Cambridge, UK: Cambridge University Press, 2008) pp. 225–247.

^{7 &}quot;Flood Hazards—A National Threat," US Geological Survey. Available at: http://pubs.usgs.gov/fs/2006/3026/2006-3026.pdf.

⁸ E. Michel-Kerjan and H. Kunreuther, "Redesigning Flood Insurance," Science 333 (6041) (2011): 408-409.

¹⁰ Hay et al, "Probabilistic reanalysis of twentieth-century sea-level rise," Nature 517 (22) (2015): 481-484.

¹¹ Goddard et al, "An extreme event of sea-level rise along the Northeast coast of North America in 2009–2010," *Nature Communications* 6 (6346) (2015).

¹² James Gerken, "Sea Levels Along The Northeast Rose Almost 4 Inches In Just 2 Years: Study," *The Huffington Post*, February 25, 2015, http://www.huffingtonpost.com/2015/02/25/sea-level-rise-northeast_n_6751570.html?ncid=tweetlnkushpmg00000048.

¹³ E.M. Spanger-Siegfried, M.F. Fitzpatrick, and K. Dahl, "Encroaching tides: How sea level rise and tidal flooding threaten U.S. East and Gulf Coast communities over the next 30 years," Cambridge, MA: Union of Concerned Scientists, 2014, http://www.ucsusa.org/ global_warming/impacts/effects-of-tidal-flooding-and-sea-level-rise-east-coast-gulf-of-mexico#.VIS8IGfbLcs.

¹⁴ Neumann et al, "Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment," PLoS ONE, (2015). The low elevation coastal zone (LECZ) is commonly defined as the contiguous and hydrologically connected zone of land along the coast and below 10 m of elevation.

About the authors

Dr. Dinah A. Koehler

Editor-in-chief and lead author

Dinah A. Koehler is a Director in UBS Asset Management Sustainable Investors Team, New York. She has 25 years of experience working on sustainability issues in academia, consulting, government and global corporations. She holds a Doctor of Science from Harvard School of Public Health.

Bruno Bertocci

Author

Bruno Bertocci is a Managing Director and Head of the UBS Asset Management Sustainable Investors Team, Chicago. Bruno has been a global investor for thirty-five years. For the last eight years he has led the development of the positive screening approach to sustainable investing, building on previous experience at Rockefeller & Co. He has an MBA from Harvard Business School.

Dr. Jonathan J. Buonocore

Author

Dr. Jonathan J. Buonocore is a Research Associate at the Center for Health and the Global Environment at the Harvard T.H. Chan School of Public Health. He is leading multiple research projects on health, climate, and environmental impacts and benefits of energy technologies and policies, ranging from health impacts of hydraulic fracturing to health benefits of different methods for carbon mitigation. Jonathan received his Sc.D. in Environmental Science and Risk Management and MS in Environmental Health from Harvard School of Public Health, and a BS in Environmental Science & Policy from Clarkson University.

Paul Donovan

Author

Paul Donovan is a Managing Director and the Global Economist for UBS Investment Bank, based in London. He is responsible for formulating and presenting the UBS global macroeconomic view. Paul holds an MA from Oxford University, an MSc from the University of London and is an honorary fellow of St Anne's College Oxford.

Andi Gordon

Author

Andi Gordon is currently pursuing an MS degree in Environmental Health from Harvard T. H. Chan School of Public Health. She holds an MPT from University of Utah, is a LEED AP and has certificates in Sustainable Design and Permaculture. She consults in residential green building and design and worked as a physical therapist in both a clinical and research settings.

Dr. Howard Kunreuther

Author

Howard Kunreuther is the James D. Dinan Professor of Decision Sciences and Public Policy, the Wharton School University of Pennsylvania and co-director of the Wharton Risk Management and Decision Processes Center. He has a long-standing interest in the management of low-probability, high-consequence events related to technological and natural hazards. He is a Fellow of the American Association for the Advancement of Science and has served on the Intergovernmental Panel on Climate Change (working group 3), World Economic Forum, National Academy of Science and NYC Panel on Climate Change among many other initiatives.

Disclaimer

This publication has been prepared for general guidance on matters of interest only, and does not constitute professional advice of any kind. You should not act upon the information contained in this publication without obtaining specific professional advice.

This document does not constitute an offer to sell or a solicitation to offer to buy any securities and nothing in this document shall limit or restrict the particular terms of any specific offering. Offers will be made only to qualified investors by means of a prospectus or confidential private placement memorandum providing information as to the specifics of the offering. No offer of any interest in any product will be made in any jurisdiction in which the offer, solicitation or sale is not permitted, or to any person to whom it is unlawful to make such offer, solicitation or sale. This document does not replace portfolio and fund-specific materials. Commentary is at a macro or strategy level and is not with reference to any registered or other mutual fund.

The information and opinions contained in this document have been complied or arrived at based upon information obtained from sources believed to be reliable and in good faith. All such information and opinions are subject to change without notice. A number of the comments in this document are based on current expectations and are considered "forward-looking statements." Actual future results, however, may prove to be different from expectations. The opinions expressed are a reflection of UBS's best judgment at the time this report is compiled, and any obligation to update or alter forwardlooking statement as a result of new information, future events, or otherwise is disclaimed. Furthermore, these views are not intended to predict or guarantee the future performance of any individual security, asset class, markets generally, nor are they intended to predict the future performance of any account, portfolio or fund.

The analysis contained herein is based on numerous assumptions. Different assumptions could result in materially different results. Opinions expressed herein may differ or be contrary to those expressed by other business areas or divisions of UBS as a result of using different assumptions and/or criteria. The value of investments and the income from them may go down as well as up and investors may not get back the original amount invested. Past performance is no guarantee of future results. Potential for profit is accompanied by the possibility of loss.

This document is not intended to provide, and should not be relied upon for, accounting, legal or tax advice, or investment recommendations. Any accounting, legal or taxation position described in this presentation is a general statement and should only be used as a guide. It does not constitute accounting, legal or tax advice and is based on an understanding of current laws and their interpretation. As individual situations may differ, clients should seek independent professional tax, legal, accounting or other specialist advisors as to the legal and tax implication of investing.

External Asset Managers / External Financial Consultants: In case this research or publication is provided to an External Asset Manager or an External Financial Consultant, UBS expressly prohibits that it is redistributed by the External Asset Manager or the External Financial Consultant and is made available to their clients and/or third parties. **Australia:** 1) **Clients of UBS Wealth Management Australia Ltd:** This notice is issued by UBS Wealth Management Australia Ltd ABN 50 005 311 937 (Holder of Australian Financial Services Licence No. 231127): This Document is general in nature and does not constitute personal financial product advice. The Document does not take into account any person's objectives, financial situation or needs, and a recipient should obtain advice from an independent financial adviser and consider any relevant offer or disclosure document prior to making any investment decisions. 2) Clients of UBS AG: This notice is issued by UBS AG ABN 47 088 129 613 (Holder of Australian Financial Services Licence No 231087): This Document is issued and distributed by UBS AG. This is the case despite anything to the contrary in the Document. The Document is intended for use only by "Wholesale Clients" as defined in section 761G ("Wholesale Clients") of the Corporations Act 2001 (Cth) ("Corporations Act"). In no circumstances may the Document be made available by UBS AG to a "Retail Client" as defined in section 761G of the Corporations Act. UBS AG's research services are only available to Wholesale Clients. The Document is general information only and does not take into account any person's investment objectives, financial and taxation situation or particular needs. Bahamas: This publication is distributed to private clients of UBS (Bahamas) Ltd and is not intended for distribution to persons designated as a Bahamian citizen or resident under the Bahamas Exchange Control Regulations. Bahrain: UBS AG is a Swiss bank not licensed, supervised or regulated in Bahrain by the Central Bank of Bahrain and does not undertake banking or investment business activities in Bahrain. Therefore, Clients have no protection under local banking and investment services laws and regulations. Belgium: This publication is not intended to constitute a public offering or a comparable solicitation under Belgian law, but might be made available for information purposes to clients of UBS Belgium, branch of UBS (Luxembourg) SA, registered with the National Bank of Belgian and authorized by the "Financial Services and Markets Authority", to which this publication has not been submitted for approval. Brazil: Prepared by UBS Brasil Administradora de Valores Mobiliários Ltda, entity regulated by Comissão de Valores Mobiliários ("CVM") Canada: In Canada, this publication is distributed to clients of UBS Wealth Management Canada by UBS Investment Management Canada Inc. **Dubai:** Research is issued by UBS AG Dubai Branch within the DIFC, is intended for professional clients only and is not for onward distribution within the United Arab Emirates. France: This publication is distributed by UBS (France) S.A., French "société anonyme" with share capital of € 125.726.944, 69, boulevard Haussmann F-75008 Paris, R.C.S. Paris B 421 255 670, to its clients and prospects. UBS (France) S.A. is a provider of investment services duly authorized according to the terms of the "Code Monétaire et Financier", regulated by French banking and financial authorities as the "Autorité de Contrôle Prudentiel et de Résolution." Germany: The issuer under German Law is UBS Deutschland AG, Bockenheimer Landstrasse 2-4, 60306 Frankfurt am Main. UBS Deutschland AG is authorized and regulated by the "Bundesanstalt für Finanzdienstleistungsaufsicht". Hong Kong: This publication is distributed to clients of UBS AG Hong Kong Branch by UBS AG Hong Kong Branch, a licensed bank under the Hong Kong Banking Ordinance and a registered institution under the Securities and Futures Ordinance. India: Distributed by UBS Securities India Private Ltd. 2/F, 2 North Avenue, Maker Maxity, Bandra Kurla Complex, Bandra (East), Mumbai (India) 400051. Phone: +912261556000. SEBI Registration Numbers: NSE (Capital Market Segment): INB230951431, NSE (F&O Segment) INF230951431, BSE (Capital Market Segment) INB010951437. Indonesia: This research or publication is not intended and not prepared for purposes of public offering of securities under the Indonesian Capital Market Law and its implementing regulations. Securities mentioned in this material have not been, and will not be, registered under the Indonesian Capital Market Law and Regulations. Israel: UBS AG is registered as a Foreign Dealer in cooperation with UBS Wealth Management Israel Ltd, a wholly owned UBS subsidiary. UBS Wealth Management Israel Ltd is a licensed Portfolio Manager which engages also in Investment Marketing and is regulated by the Israel Securities Authority. This publication shall not replace any investment advice and/or investment marketing provided by a relevant licensee which is adjusted

to your personal needs. Italy: This publication is distributed to the clients of UBS (Italia) S.p.A., via del vecchio politecnico 3, Milano, an Italian bank duly authorized by Bank of Italy to the provision of financial services and supervised by "Consob" and Bank of Italy. UBS Italia has not participated in the production of the publication and of the research on investments and financial analysis herein contained. Jersey: UBS AG, Jersey Branch, is regulated and authorized by the Jersey Financial Services Commission for the conduct of banking, funds and investment business. Luxembourg: This publication is not intended to constitute a public offer under Luxembourg law, but might be made available for information purposes to clients of UBS (Luxembourg) S.A., 33A avenue J.F. Kennedy, L-1855 Luxembourg, R.C.S. Luxembourg B 11142, a regulated bank under the supervision of the "Commission de Surveillance du Secteur Financier" (CSSF), to which this publication has not been submitted for approval. Mexico: This document has been distributed by UBS Asesores México, S.A. de C.V., a company which is not part of UBS Grupo Financiero, S.A. de C.V. or of any other Mexican financial group and whose obligations are not guaranteed by any third party. UBS Asesores México, S.A. de C.V. does not guarantee any yield whatsoever. Netherlands: This publication is not intended to constitute a public offering or a comparable solicitation under Dutch law, but might be made available for information purposes to clients of UBS Bank (Netherlands) B.V., a regulated bank under the supervision of "De Nederlansche Bank" (DNB) and "Autoriteit Financiële Markten" (AFM), to which this publication has not been submitted for approval. New Zealand: This notice is distributed to clients of UBS Wealth Management Australia Limited ABN 50 005 311 937 (Holder of Australian Financial Services Licence No. 231127), Chifley Tower, 2 Chifley Square, Sydney, New South Wales, NSW 2000, by UBS Wealth Management Australia Ltd. You are being provided with this UBS publication or material because you have indicated to UBS that you are a client certified as a wholesale investor and/or an eligible investor ("Certified Client") located in New Zealand. This publication or material is not intended for clients who are not Certified Clients ("Non-Certified Clients"), and if you are a Non-Certified Client you must not rely on this publication or material. If despite this warning you nevertheless rely on this publication or material, you hereby (i) acknowledge that you may not rely on the content of this publication or material and that any recommendations or opinions in this publication or material are not made or provided to you, and (ii) to the maximum extent permitted by law (a) indemnify UBS and its associates or related entities (and their respective directors, officers, agents and advisers (each a "Relevant Person") for any loss, damage, liability or claim any of them may incur or suffer as a result of, or in connection with, your unauthorised reliance on this publication or material and (b) waive any rights or remedies you may have against any Relevant Person for (or in respect of) any loss, damage, liability or claim you may incur or suffer as a result of, or in connection with, your unauthorised reliance on this publication or material. Saudi Arabia: This publication has been approved by UBS Saudi Arabia (a subsidiary of UBS AG), a Saudi Arabian closed joint stock company incorporated in the Kingdom of Saudi Arabia under commercial register number 1010257812 having its registered office at Tatweer Towers, P.O. Box 75724, Riyadh 11588, Kingdom of Saudi Arabia. UBS Saudi Arabia is authorized and regulated by the Capital Market Authority of Saudi Arabia. Singapore: Please contact UBS AG Singapore branch, an exempt financial adviser under the Singapore Financial Advisers Act (Cap. 110) and a wholesale bank licensed under the Singapore Banking Act (Cap. 19) regulated by the Monetary Authority of Singapore, in respect of any matters arising from, or in connection with, the analysis or report. Spain: This publication is distributed to clients of UBS Bank, S.A. by UBS Bank, S.A., a bank registered with the Bank of Spain. Taiwan: This material is provided in accordance with laws of Taiwan, in agreement with or at the request of clients. **UAE:** This research report is not intended to constitute an offer, sale or delivery of shares or other securities under the laws of the United Arab Emirates (UAE). The contents of this report have not been and will not be approved by any authority in the United Arab Emirates including the UAE Central Bank or Dubai Financial Authorities, the Emirates Securities and Commodities Authority, the Dubai Financial Market, the Abu Dhabi Securities market or any other UAE exchange. UK: Approved by UBS AG, authorised and regulated by the Financial Market Supervisory Authority in Switzerland. In the United Kingdom, UBS AG is authorised by the Prudential Regulation Authority and subject to regulation by the Financial Conduct Authority and limited regulation by the Prudential Regulation Authority. Details about the extent of our regulation by the Prudential Regulation Authority are available from us on request. A member of the London Stock Exchange. This publication is distributed to private clients of UBS London in the UK. Where products or services are provided from outside the UK, they will not be covered by the UK regulatory regime or the Financial Services Compensation Scheme. USA: This document is not intended for distribution into the US and/or to US persons. UBS Securities LLC is a subsidiary of UBS AG and an affiliate of UBS Financial Services Inc., UBS Financial Services Inc. is a subsidiary of UBS AG.

Version 05/2015.

© UBS 2016. The key symbol and UBS are among the registered and unregistered trademarks of UBS. All rights reserved.

