Climate Pragmatism Workshop Background Paper
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Our previous work on the Climate Pragmatism project focused on universal and equitable energy access as a key driver of socioeconomic development and a critical source of innovations that can push the global energy system along more equitable and cleaner pathways. Socioeconomic development and improved innovation capacity are equally critical for building resilient societies that can adapt to the uncertain impacts of a changing climate. Emphasizing the importance of adaptation and resilience opens up space for innovations in key aspects of societal infrastructure that directly improve peoples' lives in ways unavailable to an emissions-focused climate program. This paper lays out some of the ways that innovation—often spurred by experience with extreme phenomena like hurricanes, earthquakes, and drought—can improve adaptive capacity, which is particularly urgent in the developing countries that are disproportionately harmed by natural disasters. It also identifies some critical questions for an adaptation-focused agenda: How do we build or reshape our public institutions to be more responsive and adaptive? What kinds of innovations can support improved adaptive capacity? How can better coordination among decision-makers, scientists, and the public facilitate innovative adaptation strategies? How do we ensure that we learn from natural disasters in ways that improve resilience? And by reflecting on such questions, can the role and importance of adaptation be newly imagined and reframed to help motivate effective political and social action?

Introduction

The strategy for addressing climate change for the past two decades has been to focus on mitigation: to limit or reverse the increasing concentrations of climate-warming greenhouse gases (GHGs) in our atmosphere. Advocates of a mitigation-focused approach stress that an unprecedented transformation in the ways society and economies function must be rapid and global in order to avoid the tremendous risks posed by a changing climate. But anyone following international climate negotiations is well aware that it has proved difficult if not impossible for countries to commit to, let alone achieve, limits on their emissions. The benefits of reducing emissions are long-term, uncertain, and broadly diffused, in sharp contrast to the costs, which are short-term, certain, and readily perceived. In particular, where emissions-reduction policies conflict with the imperatives of economic growth, the latter usually wins out—this is the iron law of climate policy that many emissions reduction advocates have chosen to downplay or ignore.[1]

However, there is little reason that the costs and benefits must be so unbalanced; the benefits of traditional climate strategies are meager because they are couched in concepts like GHG emissions, atmospheric concentrations of CO_2, and average global temperatures. These are abstract scientific and political constructs that have little to do with people's lives. To be clear, these are measurable phenomena, and rising lev-

[1] Roger Pielke, Jr., The Climate Fix: What Scientists and Politicians Won't Tell You About Global Warming (New York, NY: Basic Books, 2010).
[2] Foreign Policy In Focus and Walden Bello, "Yes, Typhoon Haiyan Was Caused by Climate Change," *The Nation* (11 Nov. 2013),

els of heat-trapping gases in the atmosphere are changing the climate. But no one has ever *felt* a reduction in GHG emissions or an increase in average atmospheric temperature—let alone their benefits. To a person struggling to make a living, avoiding a two-degree increase in global temperatures over the next century means little, and strategies to that effect have had little political traction.

Nevertheless, mitigating emissions continues to be central to discussions about climate change. Extreme weather, such as the recent devastating typhoon in the Philippines, is often coopted in support of conventional approaches to the climate challenge through "radical emissions cuts immediately."[2] Reducing global carbon dioxide emissions may mitigate some climate impacts in the distant future, but the uncertainty of that benefit, the high immediate costs, and the warming to which the planet is already committed means that this focus has no constructive relevance to communities overwhelmed by disasters like Haiyan. An emissions-focused approach, then, has produced few if any benefits for at-risk populations, when it is not actively harming these populations' adaptive capacity by limiting development prospects. Nor, as evidenced by the ongoing failure of climate negotiations, has this strategy been able to produce anything close to "radical emissions cuts."

Focusing on adaptations that increase readiness for and resilience to threats from a range of sources is a much more effective way to protect vulnerable populations from hazards like climate change. Responding to sources of risk—rising sea levels, terrorism, economic recessions, disease pandemics, demographic and technological changes—can best be improved either indirectly, through social and economic development, or directly, through the kind of innovative adaptations discussed in this paper.

Safeguarding communities from the many risks they face now and in the future means strengthening the ability of individuals, organizations, and governments to innovate, adapt, and prosper—both in response to specific threats and during ordinary times. This approach yields a variety of near-term improvements to people's lives and livelihoods, from innovative agricultural practices that increase yields to more reliable ways of delivering energy to consumers. Linked to a development agenda grounded in capacity building and innovation, these efforts thus find a much better balance between the costs of mitigating risks and the actual benefits that mitigation can produce—a balance that has escaped climate negotiations.

As we have stressed in our earlier work,[3] a framework focused on energy access, innovation, and adaptation has greater potential for actions that benefit the world's

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[2] Foreign Policy In Focus and Walden Bello, "Yes, Typhoon Haiyan Was Caused by Climate Change," *The Nation* (11 Nov. 2013), available at: http://www.thenation.com/blog/177111/yes-typhoon-haiyan-was-caused-climate-change#

[3] Gwyn Prins, Isabel Galiana, Christopher Green, Reiner Grundmann, Mike Hulme, Atte Korhola, Frank Laird, Ted Nordhaus, Roger Pielke, Jr., Steve Rayner, Daniel Sarewitz, Michael Shellenberger, Nico Stehr, and Hiroyuki Tezuka, *The Hartwell Paper: A new direction for climate policy after the crash of 2009* (Oxford, London, UK: Institute for Science, Innovation and Society, University of Oxford and LSE Mackinder Programme, London School of Economics and Political Science, 2010); and Rob Atkinson, Netra Chhetri, Joshua Freed, Isabel Galiana, Christopher Green, Steven Hayward, Jesse Jenkins, Elizabeth Malone, Ted Nordhaus, Roger Pielke Jr., Gwyn Prins, Steve Rayner, Daniel Sarewitz, and Michael Shellenberger, *Climate Pragmatism: Innovation, Resilience, and No Regrets* (Oakland, CA: The Breakthrough Institute, 2011).

poor. Through equitable and faster development, we produce a global society that is better able to manage the risks posed by a changing climate, new technologies, and dynamic social and economic systems. Greater resiliency offers clear advantages, and often presents economic opportunities and environmental improvements (including emissions reductions) as well. But as we will discuss, there are significant hurdles that must be overcome if we are to develop more robust decision-making and adaptation practices, and innovation will play an important role in meeting these challenges.

This paper builds on the insight that an effective adaptive response to climate change requires innovation—technological, institutional, and social. Climate change should be considered a challenge of human ingenuity, rather than a test of our ever-failing ability to undertake the herculean—and likely impossible—task of transforming nearly every aspect of our lives in the name of emissions reductions. The concept of innovation draws attention to a broad set of pragmatic adaptive practices, and reframes the climate challenge away from the idea that adaptation is a regrettable "Plan B" contingency, toward the recognition that innovation-led adaptation builds on a historical trajectory of successful societies while providing the positive results and learning that can catalyze climate policies in the near term.

What We Talk About When We Talk About Adaptation

Examples abound of innovative responses to a variety of risks, from food insecurity to extreme weather. *Many of these adaptations are not directly connected to climate change, but they offer resiliency to potential dangers and opportunities for benefits that extend far beyond the uncertain impacts of a changing climate.*

Public Health and Extreme Heat

After disasters, it becomes possible to chart the geography of risk: to discover which communities and sectors suffered disproportionately, and determine vulnerabilities to future events that may not have been evident prior to the crisis. Social scientists have found that the individuals most vulnerable to a range of hazards tend to be those with the weakest ties to their communities—the old, very young, infirm, poor, or otherwise marginalized.[4] Advance warning of dangers do little to help these individuals, and they often lack the ability to access even basic services (like transportation, healthcare, or public shelters) that can help them cope with extreme events.

The deadly 1995 heat wave in Chicago, Illinois provided ample evidence of this kind of vulnerability. A disproportionate number of the 739 people who died from the heat were elderly and African American, living alone in poor, violent, segregated neighborhoods. But not all communities with these characteristics suffered equally. In demographically similar neighborhoods, but ones where businesses had not fled and community organizations remained active, people survived the heat wave at rates comparable to or exceeding more affluent areas of the city. Churches, block

[4] Kenneth Hewitt, *Regions of Risk: A Geographical Introduction to Disasters* (New York, NY: Routledge, 1997).

clubs, and especially commercial activity, provided an informal social support network that ensured many fewer people died during the city's worst natural disaster.[5]

Poor and marginalized individuals may remain isolated and alone during other crises, such as flooding, hurricanes, earthquakes, or influenza outbreaks.[6] Improving social bonds among these individuals and with the broader community thus offers a powerful form of resiliency that addresses not only the threats from these kinds of extreme phenomena, but improves the overall health of individuals and communities. The benefits of strong social capital range from reduced obesity and diabetes rates,[7] to lower levels of crime,[8] to longer life spans.[9] With these impacts in mind, over the past fifteen years the Centers for Disease Control and Prevention has launched community engagement programs in various U.S. cities to build and strengthen the kinds of local social infrastructure that help vulnerable communities deal with hazards and address public health concerns like smoking, cancer, and heart disease.[10]

Crop Innovation in Nepal

Nepal provides a good example of responsive, innovative institutions that support resiliency—in this case, improved food security. Institutional collaboration between scientists and farmers in a participatory plant breeding (PPB) program was implemented in the mid-1980s. The goal of the initiative was to develop new varieties of rice that could produce significant yields at high altitudes and in poor soil conditions, with resistance to insects, disease, and water variability. By consulting with groups of farmers and women, scientists created several rice varieties that met local needs and preferences, such as high water absorption capacity (an important trait in food-deficit areas, since absorbency ensures a greater volume of cooked rice) and cold tolerance.

By developing rice varieties that can grow in places they were not able to previously, this kind of innovation contributes to both climate adaptation and food security. These new rice varieties are the result of a collaborative breeding approach, enhancing the institutional and technological skills of farmers and communities in plant breeding, seed production, and marketing.[11] This kind of collaboration, facilitated by community-based institutions, allows knowledge to flow between key groups—

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[5] Eric Martin Klinenberg, "Dying Alone: A Social Autopsy of the 1995 Chicago Heat Wave" (PhD dissertation, University of California, Berkeley, 2000).
[6] Christopher R. Browning, Seth L. Feinberg, Danielle Wallace, and Kathleen A. Cagney, "Neighborhood Social Processes, Physical Conditions, and Disaster-Related Mortality: The Case of the 1995 Chicago Heat Wave," *American Sociological Review*, Vol. 71, No. 4 (2006), pp. 661-678.
[7] CTSA Community Engagement Key Function Committee Task Force, *Principles of Community Engagement*, 2nd Ed. (Washington, DC: National Institutes of Health, 2011).
[8] Robert D. Putnam, *Bowling Alone: The Collapse and Revival of American Community* (New York, NY: Simon & Schuster, 2001).
[9] Eric Klinenberg, "Adaptation: How can cities be 'climate-proofed'?" *The New Yorker* (7 Jan. 2013), pp. 32-37.
[10] CTSA Community Engagement Key Function Committee Task Force, *Principles of Community Engagement*, 2nd Ed. (Washington, DC: National Institutes of Health, 2011).
[11] Bhuwon Sthapit, Abishkar Subedi, Pitambar Shrestha, Pashupati Chaudhary, Pratap Shrestha, and Madhusudan Upadhyay, "Practices supporting community management of farmers' varieties," in *Farmers, Seeds, and Varieties: Supporting Informal Seed Supply in Ethiopia*, M. H. Thijssen, Z. Bishaw, A. Beshir, and W. S. de Boef, eds. (Wageningen, Netherlands, Wageningen International, 2008).

breeders gain information about the farmers' preferences for specific traits, and farmers learn about and experiment with improved varieties. Innovative institutions like the PPB program develop new information and technology aimed at improving resilience; coordinate with social groups and individuals; and can provide financial and leadership support that strengthens local institutional capacities.[12]

Disaster Preparedness in Bangladesh

Bangladesh is located in a particularly hazard-prone part of the world. An average of five cyclones per year form in the Bay of Bengal, nearly a fifth of which make landfall along Bangladesh's southern coast. Most of the country occupies a floodplain that is frequently inundated by three silt-heavy rivers. Earthquakes occasionally impact the country as two continental plates slowly crumple into each other beneath the Himalayas.[13] But these same hazards are the result of the features that make Bangladesh an exceptionally fertile land, and explain why this delta has been inhabited for centuries. Rainfall from storms swells the rivers descending from the seismic Himalayas. These overflowing rivers, in turn, deposit the silt that supports the country's agriculture.

So how does a poor, populous nation adapt to these ever-present hazards? Relocating tremendous numbers of people to safer communities is not possible in a cramped country like Bangladesh. Massive infrastructure projects, although proposed and attempted throughout the 1970s and '80s, failed to provide adequate protection against flooding and cyclones. So Bangladesh made use of its most cost-effective resource—the social capital embodied in the country's coastal and riparian communities. The government, collaborating with the Red Crescent Society and local communities, established a system to transmit hazard warnings and built thousands of public storm shelters. Using radio broadcasts and signal flags, the system depends on thousands of volunteers who disseminate cyclone warnings and evacuation information via bullhorns, bicycle-mounted loudspeakers, and house-to-house visits.[14]

As a result, cyclone preparedness has markedly improved, and fewer people die in the annual storms. During the immensely powerful Cyclone Sidr in 2007, the government mobilized 44,000 volunteers to evacuate around 3 million people, half of whom waited out the storm in public shelters. The 4,400 dead or missing as a result of the cyclone was significantly less than experienced in comparable storms. Bangladesh is still vulnerable; urbanization, for example, has concentrated exposure to risks, political disputes with neighboring countries have frustrated efforts to manage water systems, and infrastructure projects have increased risks in some places

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[12] Arun Agrawal, *The Role of Local Institutions in Adaptation to Climate Change*, paper prepared for the Social Dimensions of Climate Change, Social Development Department (Washington, DC: The World Bank, 5-6 Mar. 2008).
[13] World Bank, "Spotlight 1 on Bangladesh," in *Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention* (Washington, DC: The International Bank for Reconstruction and Development / The World Bank, 2010), pp. 34-39.
[14] Bimal Kanti Paul, "Why relatively fewer people died? The case of Bangladesh's Cyclone Sidr," *Natural Hazards*, Vol. 50, No. 2 (2009), pp. 289-304.

while protecting others.[15] But the public engagement and social capital that facilitated Bangladesh's innovative warning and evacuation system can help it navigate these difficult issues.

Water Management in the Netherlands

The Dutch, too, live with the constant threat of inundation, and have been engaged with an ongoing process of adaptation for more than a thousand years. They have essentially carved their country out of the North Sea through engineering prowess, innovative institutions, and collective action.[16] Future challenges for the country include rising sea levels, sinking land, and changing precipitation patterns.[17] But these risks are well understood, and the country has the adaptive capacity to deal with them for the foreseeable future. What is much more uncertain is Dutch social and economic development, which can radically change exposure to risk in unpredictable ways; as in many other affluent countries, the dangers stem not from the sea or climatic variability, but from economic changes, demographic shifts, and land-use policies.[18]

Many of the dangers facing the Netherlands are similar to those of Bangladesh—flooding, storms, and the ongoing concentration of wealth in vulnerable areas. The Dutch have used their considerable financial resources to mitigate these dangers through capital-intensive systems of dikes, dams, seawalls, and other protective infrastructure. But reclaiming and protecting land from the sea also necessitates forms of social capital like that mobilized for adaptation in Bangladesh. Local water boards were organized as long ago as the 13th century as a form of democratic governance that allows citizens to make decisions about how best to confront collective risks.[19] These institutions improve not just the capacity to deal with water, but to decide on other adaptive practices, such as, for example, increasing the extraordinary reliability of the Netherlands' power grid.[20]

Preparing for Tsunamis

Effective adaptation, like other innovation processes, requires learning from past experience, experimenting with novel practices and technologies, and participating in a network of people who can share and evaluate adaptations that emerge from particular contexts. During the Indian Ocean tsunami in 2004, for example, inhabitants of Simeulue Island knew to head into the mountains when they saw the ocean retreating, through knowledge passed down from previous generations who had

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[15] World Bank, "Spotlight 1 on Bangladesh," in *Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention* (Washington, DC: The International Bank for Reconstruction and Development / The World Bank, 2010), pp. 34-39.
[16] Rutger van der Brugge, Jan Rotmans, Derk Loorback, "The transition in Dutch water management," *Regional Environmental Change*, Vol. 5 (2005), pp. 164-176.
[17] Paul J. M. van Steen and Piet H. Pellenbarg, "Water Management Challenges in the Netherlands," *Tijdschrift voor Economische en Sociale Geografie*, Vol. 95, No. 5 (2004), pp. 590-598.
[18] Frans Klijn, Karin M. de Bruijn, Joost Knoop, Jaap Kwadijk, "Assessment of the Netherlands' Flood Risk Management Policy Under Global Change," *AMBIO*, Vol. 41 (2012), pp. 180-192.
[19] Paul J. M. van Steen and Piet H. Pellenbarg, "Water Management Challenges in the Netherlands," *Tijdschrift voor Economische en Sociale Geografie*, Vol. 95, No. 5 (2004), pp. 590-598.
[20] Eric Klinenberg, "Adaptation: How can cities be 'climate-proofed'?" *The New Yorker* (7 Jan. 2013), pp. 32-37.

experienced a deadly tsunami in 1907. They survived in much greater numbers than residents of Banda Aceh, who did not have that knowledge. Several programs since that disaster have sought to educate coastal communities about what to do for the next tsunami, using social networks and institutions to provide information, rather than high-tech measures that are prone to malfunctions, incomprehension, or inadequacy.[21]

It may be impossible for coastal communities, particularly in densely populated cities, to reach higher ground even if adequately warned of an approaching tsunami. In a neat reversal of traditional evacuation plans, one innovative approach seeks to bring higher ground to vulnerable communities in the form of elevated parks. A half-dozen elevated parks in the Indonesian city of Padang could save as many as 100,000 people from the threat of inundation. Simple, relatively inexpensive, and reassuring to the city's inhabitants, this innovation depends more on knowledge of a particular social and institutional context than of the intricacies of tsunamis and their causes.[22]

Maladaption in Sub-Saharan Africa

The long list of reasons why many communities in sub-Saharan Africa suffer not just from poverty, but the related burden of energy poverty in particular, includes poor infrastructure, political corruption, weak institutions and governance, and lack of access to capital. This situation has not been helped by a climate strategy that is often focused on emissions reductions whenever and wherever possible. The dynamic and growing urban centers of Africa require large-scale, centralized energy sources along with efficient networks of gas pipelines and electricity grids.[23] This kind of energy sector development—one that underpins prosperous and resilient societies—lies mostly outside the framework within which energy, development, and climate change is often understood.

The conspicuous lack of access to modern energy sources in sub-Saharan countries has resulted in a staggering 80% of urban households that use charcoal for cooking and heating. Charcoal contains more energy, burns with less smoke, and is easier to transport than firewood. But charcoal production has created swathes of deforested land around cities like Addis Ababa, Lusaka, and Dakar, and its use indoors causes considerable health problems.[24] Without assistance in providing reliable grid-based electricity to their urban centers, countries like Zambia remain vulnerable to both the direct risks of flooding and landslides caused by deforestation, and are deprived of the opportunities for socioeconomic development presented by energy access.

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[21] Julie Morin, "Tsunami-resilient communities' development in Indonesia through educative actions," *Disaster Prevention and Management*, Vol. 17, No. 3 (2008), pp. 430-446.
[22] Daniel Sarewitz, "Brick by brick," *Nature*, Vol. 465 (6 May 2010), p. 29.
[23] See Jesse H. Ausubel, "Decarbonization: The Next 100 Years" (Austin, TX: 50th Anniversary Symposium of the Geology Foundation, Jackson School of Geosciences, University of Texas, Apr. 25, 2003).
[24] Werner L. Kutsch et al., "The Charcoal Trap: Miombo forests and the energy needs of people," *Carbon Balance and Management*, Vol. 6 (2011); and Leo C. Zulu and Robert B. Richardson, "Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa," *Energy for Sustainable Development* (2012).

The Lessons for Innovative Adaptation

The cases above illustrate how innovative approaches to adaptation can not only reduce vulnerabilities to hazards but present opportunities for benefits that exceed merely mitigating damages. Adaptation is a dynamic process whereby societies continually respond to changing situations by taking action in response to or in anticipation of these new conditions. Rather than seeking only to reduce disaster damage, the most effective adaptation strategies support and strengthen social health and prosperity. They may be components of a broader socioeconomic development agenda such as improved energy access, or they may directly improve adaptation through innovation—Indonesia's elevated parks, for example.

The degree to which extreme events are damaging to human lives and livelihoods is not predicated on knowing with accuracy when or where they will happen. Rather, adaptation depends on the capacity and willingness on the part of individuals, institutions, and societies to incorporate new knowledge and make beneficial changes—to innovate—in order to become more resilient.[25] Far from being a new activity undertaken in response to human-induced climate change, innovating to deal with a variable world is something people have always done. Yet much of what we know about how innovation works, and how it can be used to manage uncertainties, has yet to be captured in discussions of adaptation.

Humans excel at innovation-led adaptation, and a range of adaptations has lessened the vulnerability of human systems to climatic challenges.[26] Examples include food preservation techniques to overcome the problem of seasonal shortages; aluminum and other structural materials that resist environmental deterioration; antifreeze to safeguard internal combustion engines in the winter; and weather and earth resource satellites for analysis of weather and climate. More fundamental behavioral adaptations include farmers switching to crops that favor changed climatic conditions, or purchasing land in places that will be better suited to their crops.[27] Even more transformational are society-wide adaptations to existential threats, such as the Dutch experience discussed above.[28]

These examples suggest several characteristics of adaptive activities that are often overlooked. For one, the adaptations that improve resilience are not necessarily cutting-edge technologies. Humans have long had the tools to thrive in the harshest environments, and have developed methods for dealing with a huge array of potential disasters and climate variability.[29] Related to this point, the frontiers of climate sci-

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[25] Bruce A. Wilcox and Pierre Horwitz, "The Tsunami: Rethinking Disasters," *EcoHealth*, Vol. 2 (2005), pp. 89-90.
[26] Jesse H. Ausubel, "Does Climate Still Matter?" *Nature*, vol. 350 (25 Apr. 1991), pp. 649-652.
[27] S. E. Park, N. A. Marshall, E. Jakku, A. M. Down, S. M. Howden, E. Mendham, and A. Fleming, "Informing adaptation responses to climate change through theories of transformation," *Global Environmental Change*, Vol. 22 (2012), pp. 115-126.
[28] Rutger van der Brugge, Jan Rotmans, Derk Loorback, "The transition in Dutch water management," *Regional Environmental Change*, Vol. 5 (2005), pp. 164-176.
[29] Yujiro Hayami and Vernon W. Ruttan, *Agricultural Development: An International Perspective* (Baltimore, MD: Johns Hopkins University Press, 1985); Netra Chhetri and William Easterling, "Adapting to Climate Change: Retrospective Analysis of Climate Technology Interaction in the Rice-Based Farming System of Nepal," *Annals of the Association of American Geographers*, Vol. 100, No. 5 (2010), pp. 1156-1176.

ence—much of which appears preoccupied with refining the predictive potential of climate models—may be mostly irrelevant to adaptation.[30] The most robust technological, institutional, or social adaptations for managing climate risks do not depend on precise knowledge of the future.

In addition, despite operating on separate tracks at international climate negotiations,[31] adaptation and mitigation are not necessarily mutually exclusive strategies that compete for the same pool of resources.[32] Urban planning that prioritizes high-density, mixed-income neighborhoods, mass transit, and redundant infrastructure produces cities that are both resilient and climate-friendly.[33] Maintaining or replanting forests through improved land use, often involving more productive agriculture, contributes to carbon sequestration and biodiversity conservation, while reducing the potential for flooding and landslides.

Furthermore, some adaptation actions, such as growing more productive crops or constructing houses that do not require expensive flood insurance, are cost-effective in the short term, and are usually economically justifiable when compared with the potential losses from not adapting. In practice, however, taking the necessary actions, no matter how simple or commonsense, is rarely easy—and the transformational adaptations that may be necessary in some places pose an even greater challenge. Uncertainty, resource constraints, a lack of information or communication, inadequate incentives, bureaucratic inertia, cultural habits and preferences, and other obstacles present hurdles to developing and implementing innovative adaptations.[34]

Therefore we focus on innovations that improve *adaptive capacity*: a society's ability to take actions that ensure agricultural systems, water systems, natural hazards mitigation capabilities, and many aspects of the built environment are able to adapt rapidly—indeed, potentially with unprecedented responsiveness—in order to keep up with changing vulnerabilities to climate impacts.[35] Adaptive capacity must also balance this need for flexibility and transformation with the social imperatives of stability and continuity.[36] A society is thus considered to have high adaptive capacity

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[30] Mark Howden, Rohan A. Nelson, and Steven Crimp, "Food security under a changing climate: frontiers of science or adaptation frontiers?" Ch. 4 in *Climate Adaptation Futures*, Jean Palutikof, Sarah L. Boulter, Andrew J. Ash, Mark Stafford Smith, Martin Parry, Marie Waschka, and Daniela Guitart, eds. (Oxford, UK: John Wiley & Sons, 2013), pp. 56-68.

[31] J. R. Beddington, M. Asaduzzaman, M. E. Clark, A. Fernández Bremauntz, M. D. Guillou, D. J. B. Howlett, M. M. Jahn, E. Lin, T. Mamo, C. Negra, C. A. Nobre, R. J. Scholes, N. Van Bo, and J. Wakhungu, "What Next for Agriculture After Durban?" *Science*, Vol. 335 (20 Jan. 2012), pp. 289-290.

[32] Sally Kane and Jason F. Shogren, "Linking Adaptation and Mitigation in Climate Change Policy," *Climatic Change*, Vol. 45 (2000), pp. 75-102.

[33] Vishaan Chakrabarti, "How Density Makes Us Safer During Natural Disasters," *The Atlantic Cities* (19 Sep. 2013), available at: http://www.theatlanticcities.com/housing/2013/09/how-density-makes-us-safer-during-natural-disasters/6864/

[34] World Bank, "Beyond the ideal: Obstacles to risk management and ways to overcome them," Ch. 2 in *World Development Report 2014 – Risk and Opportunity: Managing Risk for Development* (Washington, DC: The World Bank Group, 2013), pp. 79-103.

[35] Barry Smit, Olga Pilifosova, I. Burton, B. Challenger, S. Huq, R. J. T. Klein, and G. Yohe, "Adaptation to climate change in the context of sustainable development and equity," Ch. 18 in Contribution of Working Group II to the *Third Assessment Report of the Intergovernmental Panel on Climate Change*, J. J. McCarthy, O. F. Canziano, and N. Leary, eds. (Cambridge, UK: Cambridge University Press, 2001), pp. 877–912.

[36] Lauren Rickards, Mark Howden, and Steve Crimp, "Channelling the future? The use of seasonal climate forecasts in climate adaptation," publication forthcoming.

when it has the ability to anticipate and respond to changing social and environmental contexts while maintaining or improving the wellbeing of its citizens.

Adaptive capacity has not kept pace with the magnitude and intensity of recent climate events. Instead, a rapid growth of economic losses and livelihood disruptions has occurred in many parts of the world.[37] In the United States, economic losses from natural disasters have been on the rise since the 1960s, corresponding with increasing exposure of settlements in hazard-prone areas—our propensity to build expensive housing on coastlines and to farm in floodplains, for example.[38] Adaptive capacity requires that societies improve the interwoven, underlying factors that contribute to resiliency—or, in their absence, lead to vulnerability.

With improved adaptive capacity as the goal, innovation is the means by which we achieve that goal. Innovation is a process of socioeconomic development, so a primary focus should be on accelerating the development of poor communities worldwide. Doing so, of course, is a challenge that has occupied a great deal of people for decades. But it has been hampered over the past two decades by misconceptions about how energy is connected to development and how the capacity to innovate is tied to development.[39] A good first step, as we have argued, would be to address vast inequities in access to modern energy. The development enabled by equitable, universal energy access also provides the context for a global innovation ecosystem capable of reducing the planet's reliance on fossil fuels. But development may equally depend on reducing the vulnerabilities of poor communities so that they may prosper.

The Foundations of Adaptive Capacity

The elements that comprise a society's adaptive capacity are not entirely agreed upon, but emerging literature suggests four factors that collectively contribute to adaptive capacity: *capital*, *knowledge*, *institutions*, and *governance*. Improving on these elements facilitates both socioeconomic development and a society's ability to mitigate and adapt to a changing climate.

Financial Capital

Financial capital is universally noted as one of the main determinants of adaptive capacity; put simply, wealthier countries have more resources to deal with changing conditions than poor countries. As deadly wildfires in Australia, flooding in the United Kingdom, and hurricanes in the United States attest, the wealthy are not immune to the effects of extreme events. But affluent societies are able to devote financial capital to public health and sanitation infrastructure, to ensure quality road

[37] United Nations International Strategy for Disaster Reduction Secretariat (UNISDR), *Risk and Poverty in a Changing Climate: 2009 Global Assessment Report on Disaster Risk Reduction* (Geneva, Switzerland: United Nations, 2009).
[38] Daniel Sarewitz and Roger Pielke, Jr., "Breaking the Global-Warming Gridlock," *The Atlantic* (Jul. 2000), available at: http://sciencepolicy.colorado.edu/admin/publication_files/resource-69-2000.18.pdf
[39] Rob Byrne, Adrian Smith, Jim Watson, and David Ockwell, *Energy Pathways in Low-Carbon Development: From Technology Transfer to Socio-Technical Transformation* (Brighton, UK: STEPS Centre, STEPS Working Paper 46, 2011).

and home construction, to train emergency responders, and to provide insurance and other financial protections to impacted communities, among many other adaptive actions.

Financial resources for adaptive action are unevenly distributed. Climate change threatens to exceed the capacities of poor countries' ability to absorb losses and recover from impacts,[40] and adverse impacts are concentrated in poor and marginalized communities worldwide.[41] With fewer resources to draw upon during periods of stress or crisis, the poor are more vulnerable to the increasing frequency and intensity of weather events, seasonal shifts in precipitation, extended periods of drought, and sea level rise. This is especially the case because subsistence communities depend directly for their livelihoods on climate-sensitive resources like fisheries, fields, and forests.[42] Effective adaptation strategies, therefore, rely on economic growth and, in the least developed countries, targeted foreign investment and aid.

Social Capital

The adaptive capacity of a society is partly determined by the presence of *social capital*, which describes relations of trust, reciprocity, and exchange; agreement on common rules; and the functioning of networks.[43] Communities require social capital in order to act collectively to address common threats—to make decisions, allocate resources, take action, and rebuild after disasters. The choices made by individuals, communities, organizations, and public institutions inevitably produce winners and losers—this is where trust, rules, and networks are important—so social capital helps generate agreement on what adaptive actions to take and how to implement them, taking into account multiple objectives, needs, preferences, and values.[44] Social capital also comes into play in the immediate aftermath of disasters, when other forms of assistance may not be available. After the devastating earthquake in Kobe, Japan in 1995, for example, government fire departments were prevented from accessing many areas because of destroyed roadways, and community-based volunteer firefighters became critical in battling conflagrations.[45]

Social capital is extraordinarily important when other components of adaptation are weak. In poor communities, where financial capital (money) and human capital (education) are lacking, social capital has long been recognized as central to coping with risk.[46] Conversely, indicators of a lack of social capital, such as public-sector corruption, authoritarian governments, and economic inequality, increase the po-

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[40] United Nations International Strategy for Disaster Reduction Secretariat (UNISDR), *Risk and Poverty in a Changing Climate: 2009 Global Assessment Report on Disaster Risk Reduction* (Geneva, Switzerland: United Nations, 2009).
[41] Mark Pelling, *Adaptation to Climate Change: From Resilience to Transformation* (New York, NY: Routledge, 2011).
[42] Heather McGray, Rob Bradley, Anne Hammill, E. Lisa Schipper, and Jo-Ellen Parry, *Weathering the Storm: Options for Framing Adaptation and Development* (Washington, DC: World Resources Institute, Nov. 2007).
[43] W. Neil Adger, "Social Capital, Collective Action, and Adaptation to Climate Change," *Economic Geography*, Vol. 79, No. 4 (2003), pp. 387-404.
[44] Richard H. Moss and Meredith A. Lane, "Decision-making, Transitions, and Resilient Futures," *Issues in Science and Technology*, Vol. 28, No. 4 (Summer 2012).
[45] David W. Edgington, *Reconstructing Kobe: The Geography of Crisis and Opportunity* (Vancouver, Canada: UBC Press, 2010).
[46] Robin Cantor and Steve Rayner, "Changing Perceptions of Vulnerability," in *Industrial Ecology and Global Change*, Robert Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds., (New York, NY: Cambridge University Press, 1994).

tential for catastrophe in the face of extreme events.[47] Communities with weak social capital are also vulnerable to longer-term changes. For example, in KwaZulu-Natal, South Africa, a breakdown in two-parent families, divergences between religious groups, weak leadership, and cultural changes have been linked to food insecurity.[48] And as the example of the Chicago heat wave shows, heterogeneous patterns of social capital, across even a single city, can determine who disproportionately suffers, and who successfully adapts.

Knowledge

For social capital to make a difference in adapting to a changing climate, *knowledge* is essential. Knowledge determines how people perceive and respond to specific risks.[49] A well-informed population can take action to minimize risks, but this assumes timely dissemination of new knowledge of hazards, and options as to what can be done to confront them.[50] Adaptation-relevant information can come from a range of sources, from weather and climate research, to the availability of insurance, to where to go in an emergency. For example, the Dutch have developed a successful water management system by addressing recurring coastal flooding risk and recognizing the value of protective infrastructure. The strength of this model lies in the extensive education and engagement of the public in policy-making processes—although this kind of knowledge co-production demands leadership, participation, patience, and other resources that are often in short supply.

One example of this is that urban planners in the U.S. have for decades been warning of the perils of coastal flooding to emphasize the need for responsible land use. Comparison of Ian McHarg's 1969 land suitability analysis of Staten Island with damage assessments of Hurricane Sandy shows that much of the flooding caused by the storm occurred on land originally defined as unsuitable for urbanization. According to McHarg, the developed areas that were inundated by storm surges were best suited for passive recreation or conservation. Obviously, the economic and political incentives for urban development won out—but the experience of Sandy, and the larger climate change context overall, can provide opportunities to rebalance how the public understands these incentives and imagines the future.

The transmission of pertinent knowledge is a key aspect of social capital, functioning institutions, and effective governance, underscoring the fact that knowledge creation should be responsive to the adaptation needs of stakeholders and decision-makers. Bangladesh's progress in reducing cyclone losses is just one example of how

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[47] See, for example: Monica Escaleras, Nejat Anbarci, and Charles Register, "Public sector corruption and major earthquakes: A potentially deadly interaction," *Public Choice*, Vol. 132, No. 1-2 (2007), pp. 209-230; Matthew Kahn, "The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions," *The Review of Economics and Statistics*, Vol. 87, No. 2 (2005), pp. 271-284; and Nejat Anbarci, Monica Escaleras, and Charles Register, "Earthquake fatalities: the interaction of nature and political economy," *Journal of Public Economics*, Vol. 89, No. 9-10 (2005), pp. 1907-1933.

[48] Alison Misselhorn, "Is a focus on social capital useful in considering food security interventions? Insights from KwaZulu-Natal," *Development Southern Africa*, Vol. 26, No. 2 (2009), pp. 189-208.

[49] Maarten K. van Aalst, Terry Cannon, and Ian Burton, "Community level adaptation to climate change: The potential role of participatory community risk assessment," *Global Environmental Change*, Vol. 18, No. 1 (2008), pp. 165-179.

[50] J. A. Fresque-Baxter and D. Armitage, "Place, identity, and climate change adaptation: A synthesis and framework for understanding," *Climate Change*, Vol. 3, No. 3 (2012), pp. 251-266.

new knowledge and social capital can combine to provide rapid and easily discernible improvements in adaptive capacity.

Institutions

Knowledge about climate risks is not especially relevant if a society cannot use that knowledge to inform how it adapts to climate change. *Institutions* are therefore necessary for organizing collective action to make and implement adaptive policies. The social purpose of institutions is to reduce uncertainty and risks by channeling information and providing predictability to interactions,[51] so innovative institutions can mediate between individual and collective responses to climate impacts and deliver resources to facilitate adaptation.[52] Public, private, and civil society institutions—from the military, regulatory agencies, and insurance companies to healthcare facilities, schools, NGOs, and community groups—determine in large and small ways how social and environmental changes impact communities.

Formal, top-down institutions are increasingly being complemented and sometimes challenged by new forms of bottom-up collaboration.[53] Such changes are largely driven by the persistent inability of existing institutions to devise effective adaptation programs, or to coordinate among themselves to avoid redundant or conflicting policies.[54] Despite the importance accorded to the role of institutions in fostering adaptation, few researchers have investigated how climate variability might induce new institutional arrangements that can improve adaptive capacity.

Governance

Governance describes the ability of a system to devise and implement appropriate adaptation strategies conditioned by existing policies, laws, rules, regulations, programs, and mandates.[55] Governance, in other words, refers to how well (or poorly) institutions are performing their tasks of channeling information, making and enforcing rules, and providing stability to human and organizational interactions. Good governance strategies, like the other components of adaptive capacity, will have to innovate in order to address the deep uncertainties of a changing climate.

Because preventing all risks is impossible, determining socially acceptable responses to dangers is part of a political process that seeks to reconcile different—

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[51] World Bank, "Building Institutions for Markets," *World Development Report 2002* (Washington, DC: World Bank, 2002).
[52] Arun Agrawal, *The Role of Local Institutions in Adaptation to Climate Change*, paper prepared for the Social Dimensions of Climate Change, Social Development Department (Washington, DC: The World Bank, 5-6 Mar. 2008).
[53] Netra Chhetri, Pashupati Chaudhary, Puspa Raj Tiwari, and Ram Baran Yadaw, "Institutional and technological innovation: Understanding agricultural adaptation to climate change in Nepal," *Applied Geography*, Vol. 33 (Apr. 2012), pp. 142-150; and Kate Urwin and Andrew Jordan, "Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance," *Global Environmental Change*, Vol. 18 (2008), pp. 180-191.
[54] Lisa Schipper and Mark Pelling, "Disaster risk, climate change and international development: scope for, and challenges to, integration," *Disasters*, Vol. 30, No. 1 (2006), pp. 19-38; and Tom Mitchell and Maarten van Aalst, "Convergence of Disaster Risk Reduction and Climate Change Adaptation," Review for the UK Department for International Development (2008), available at: www.preventionweb.net/files/7853_ConvergenceofDRRandCCA1.pdf
[55] Susanne C. Moser and Julia A. Ekstrom, "A framework to diagnose barriers to climate change adaptation," *Proceedings of the National Academy of Sciences*, PNAS Early Edition (2010), available at: http://www.susannemoser.com/documents/Moser-Ekstrom_onlineearly.pdf

sometimes vastly different—preferences, values, and beliefs.[56] (This is why corruption, authoritarianism, and inequality, which weaken governance, can amplify social vulnerability.) Distinct perceptions of risk lead to different adaptation strategies. European countries, for example, have been mostly unwilling to cultivate genetically modified crops, despite GMOs' potential for improved climate resilience and greater food security.

Deep uncertainties about the impacts climate change will have on human and natural systems—especially at the local level where these impacts will be felt—mean that societies may not have the information they need to guide adaptive actions. Predictions about the future climate below the global level are particularly unhelpful in guiding many adaptation decisions; depending on the climate model, West Africa may receive either 25 percent more or 25 percent less rainfall by 2100.[57] How are governments in the region meant to plan for water management in the face of these conflicting predictions? While a key role of institutions is to facilitate knowledge flows, innovative governance strategies must cope with conflicting or missing predictive knowledge about the future.

Governance is not only about actions the public sector takes directly to help societies adapt to climate change. It also concerns the incentives and behavioral changes produced by legislation, regulation, taxation, or insurance, which promote or inhibit innovation on the part of individuals and the private sector. The U.S. Federal Crop Insurance program, for instance, actively discourages agricultural innovation by providing insurance coverage based on the average of several previous years' harvests. Should a farmer seek to increase yields by experimenting with a new crop variety or making operations more efficient, insurance does not cover the increased yields in the case of crop failure. Thus the farmer could lose much more than if he or she had not invested in innovation.[58]

The challenge for effective governance—and where innovation is needed—in regard to adaptive capacity is to cultivate learning and policy evolution in response to both societal and climatic changes. The examples of agricultural innovation in Nepal and water management in the Netherlands show how evolving governance models that can enhance adaptive capacity may evolve from very different institutional and social settings.

The Role of Innovation in Adaptive Capacity

The capacity of societies and nations to innovate may well be the most important determinant of economic growth, social equity, and adaptive capacity. Because the capacity to innovate in order to adapt is intertwined with processes of socioeconom-

[56] World Bank, "Beyond the ideal: Obstacles to risk management and ways to overcome them," Ch. 2 in *World Development Report 2014 – Risk and Opportunity: Managing Risk for Development* (Washington, DC: The World Bank Group, 2013), pp. 79-103.
[57] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group 1 to the Fourth Assessment Report of the IPCC (Cambridge, UK: Cambridge University Press, 2007).
[58] Michael Specter, "Climate by Numbers," *The New Yorker* (11 Nov. 2013), pp. 38-43.

ic development, an innovative adaptation agenda is, in large part, a development agenda.

The components described above are not discrete entities or practices that can be addressed separately. They are interwoven: socioeconomic development undergirds human and financial capital, which generates and supports effective institutions. Institutions that embody the principles of good governance can devote resources to creating better infrastructure and preventive technologies, more effective regulations and emergency management. These in turn help to defend a society from the worst effects of a variable and highly uncertain future.[59]

Improving adaptive capacity, then, is an ongoing, iterative process of socioeconomic development that no country, no matter how prosperous, has "achieved." Underlying the harms that natural disasters cause are practices, institutions, and technologies that can be made more responsive and adaptive through innovations that help societies withstand extreme climatic events and support a broad set of adaptive practices. These range from small-scale, highly localized improvements, like low-income mobile housing in Ho Chi Minh City, to society-wide innovations, such as improved land-use practices to reduce deforestation or unsustainable coastal development.

The linkages produced by international supply chains mean that climate impacts in a distant part of the world have unpredictable consequences. Extreme flooding in Thailand in 2012, for example, caused automobile factories in the U.S. to reduce factory hours due to a lack of parts, and forest fires in Russia in the same year raised grain prices worldwide. Encouraging adaptive innovation and technology development in less developed regions therefore produces a global public good. Coordination of these efforts makes research and development of adaptation strategies more efficient by reducing redundancies, and improves global equity in disaster risk reduction—in addition to facilitating knowledge spillovers and providing a foundation for future innovations.[60] Adaptive innovation thus stimulates a variety of other benefits, from strengthening global food security,[61] to facilitating better communication among emergency responders,[62] to increasing the economic growth supported by dynamic cities.[63]

Much like a natural ecosystem, a productive innovation ecosystem depends on diversity and nourishment. With support and investment, the landscape for innova-

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[59] Matthew Kahn, "The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions," *The Review of Economics and Statistics*, Vol. 87, No. 2 (2005), pp. 271-284

[60] Qing Miao and David Popp, *Necessity as the Mother of Invention: Innovative Responses to Natural Disasters*, Working Paper 19223 (Cambridge, MA: National Bureau of Economic Research, Jul. 2013).

[61] Netra Chhetri and William Easterling, "Adapting to Climate Change: Retrospective Analysis of Climate Technology Interaction in the Rice-Based Farming System of Nepal," *Annals of the Association of American Geographers*, Vol. 100, No. 5 (2010), pp. 1156-1176.

[62] John F. Weaver, Eve Gruntfest, and Glenn M. Levy, "Two Floods in Fort Collins, Colorado: Learning from a Natural Disaster," *Bulletin of the American Meteorological Society*, Vol. 81, No. 10 (2000), pp. 2359-2366.

[63] Vishaan Chakrabarti, "How Density Makes Us Safer During Natural Disasters," *The Atlantic Cities* (19 Sep. 2013), available at: http://www.theatlanticcities.com/housing/2013/09/how-density-makes-us-safer-during-natural-disasters/6864/

tion devoted to adaptation has the potential to become much richer and more diverse for at least two reasons. One, innovation systems are becoming increasingly sophisticated in the countries of the global South, as rapidly developing countries like Brazil, Russia, India, Mexico, China, and South Africa devote resources to their innovation capacities, and even the least developed countries are experiencing impressive economic growth rates. Two, innovative adaptation activities can be spurred by experience with extreme events, which may occur more frequently as the planet experiences the climate changes to which we have already committed ourselves, no matter how effectively we implement mitigation efforts.

Learning from Disaster

Although complex and multidimensional, crises offer opportunities for rebuilding with increased resilience. In addition, the impact of extreme events offers a metric for evaluating adaptation efforts, as the inadequacy of existing adaptations often comes to light only after disasters. Obviously, disasters extract a tremendous toll on human lives and livelihoods, and adapting only reactively to them is unacceptable—although research indicates that individuals and the private sector generally do just that. This suggests a role for the public sector in supporting the development and implementation of anticipatory risk-mitigating innovations.[64]

A challenge for adaptive innovations resulting from disasters is to ensure that improvements are structural rather than superficial. Lessons from extreme events fade quickly from public memory and drop from policymakers' priorities. Innovations that improve resilience should be developed and employed when the need for them is clear, and in ways that cannot be easily reversed when memories fade and competing interests emerge. For example, after severe flooding in 1953, the Netherlands implemented rigorous flood management standards that would be difficult to reverse.[65] This may be difficult when the rebuilding schemes of planners differ significantly from the desires of the public, who likely want the environment returned to the way it was[66]—but this is where the governance capacity of effective institutions is important.

Disasters provide a catalyzing force for motivating different sectors of society toward mutually agreeable solutions. Because they reveal the need for innovation and potential avenues for research or experimentation, the space for adaptations opened up by disasters may be comparable to what are called innovation "niches" in the study of innovation.[67] Taking advantage of these niches has the potential to produce radically new technologies, processes, or institutions that can improve our ability to withstand extreme events.

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[64] Qing Miao and David Popp, *Necessity as the Mother of Invention: Innovative Responses to Natural Disasters*, Working Paper 19223 (Cambridge, MA: National Bureau of Economic Research, Jul. 2013).
[65] World Bank, "Beyond the ideal: Obstacles to risk management and ways to overcome them," Ch. 2 in *World Development Report 2014 – Risk and Opportunity: Managing Risk for Development* (Washington, DC: The World Bank Group, 2013), pp. 79-103.
[66] David W. Edgington, *Reconstructing Kobe: The Geography of Crisis and Opportunity* (Vancouver, Canada: UBC Press, 2010).
[67] Frank W. Geels, "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study," *Research Policy*, Vol. 31 (2002), pp. 1257-1274.

Conclusion

Adaptive innovation, either induced by disasters or encouraged in advance, will become ever more critical as environmental, socioeconomic, and other changes place new demands on technology and institutions. Supporting a vibrant innovation landscape devoted to improving the resilience and adaptive capacity of communities worldwide, with a particular focus on the poor who are disproportionately harmed by extreme events, offers a pragmatic pathway to protect human dignity, livelihoods, and prospects in the face of a dynamic climate and rapidly evolving societies.