Washington Journal of Environmental Law & Policy

Volume 7 | Issue 2

7-1-2017

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INVEST TO WITHSTAND THE TEST OF TIME: CAPITAL PLANNING FOR HIGH-IMPACT EARTHQUAKES

Jan Whittington*

I. INTRODUCTION

Can people expect buildings and infrastructure to last, keeping their occupants sheltered from the elements, free to go about their business? The professionals who design facilities—as well as the taxpayers and entrepreneurs who fund them—make this assumption, but is this a safe assumption to make? Contemplate the effect of one extreme event—a magnitude 9.0 earthquake along the Cascadia Subduction Zone of the Pacific coast—and it is easy to realize that this is not a safe assumption.[1] Though seismic technology can be used to fortify structures against extreme events and land use plans can keep development out of harm's way, the adoption of these measures has not kept pace with scientific understanding of the risks, and the ensuing scenarios of mega-quakes portend widespread devastation across the urban landscape.[2] For the

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1. Ryan Haas, *What is a 9.0 Earthquake?*, OR. PUB. BROADCASTING (Sept. 25, 2015 7:37 AM), http://www.opb.org/news/series/unprepared/what-is-a-90-earthquake-/.

2. The Western Washington University Resilience Institute put together a scenario

benefit of all involved, it may be helpful to recognize the barriers that prevent people from making investments that will withstand the test of time, because many such obstacles can be overcome with sound capital investment planning. This essay situates the problem of human vulnerability to extreme earthquakes within the emerging empirical science of behavioral economics. When science makes biases in capital investment predictable, solutions become self-evident.

Many of the obstacles that stand in the way of seismically safe choices for buildings and infrastructure originate from the ways in which people view the past, present, and future. Economists have recognized for quite some time that although humans are rational thinkers, our thinking becomes distorted when asked to make a choice today in light of the past, or when making a choice today that will have lasting consequences.[3] People may have a desire to make economically

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forecasting devastation from a mega-quake, which states:

> Should the earthquake and tsunami happen tomorrow, it could affect millions of people's lives, property, infrastructure, and environment. The number of deaths could exceed 10,000, and more than 30,000 people could be injured. . . . For Washington and Oregon, the direct economic losses have been estimated at upward of $81 billion. These social and economic impacts could distress the region for years to come.

W. WASH. U. RESILIENCE INST., CASCADIA RISING EXERCISE SCENARIO DOCUMENT 20 (2015), https://assets.documentcloud.org/documents/3149654/Cascadia-Rising-2016-Exercise-Scenario.pdf. "Megaquake" is a shortened term for a "megathrust earthquake.";

> Earthquakes … [of magnitude greater than or equal to] 8.7, … present hazards to lives and property that are far more extensive than a typical 'great' earthquake. We therefore adopt the term 'megathrust earthquake' after the common usage among paleoseismologists for exceptionally destructive earthquakes.

Jeffrey Park et al., *Performance Review of the Global Seismographic Network for the Sumatra-Andaman Megathrust Earthquake*, 76 SEISMOLOGICAL RESEARCH LETTERS 331, 329 (2005); *See also Subduction Zone: Tsunamis Generated by Megathrust Earthquakes*, INC. RES. INST. FOR SEISMOLOGY, https://www.iris.edu/hq/inclass/animation/subduction_zone_tsunamis_generated_by_megathrust_earthquakes (last visited May 11, 2017) ("Megathrust earthquakes are: the most powerful earthquakes in the world [and] occur where two plates converge particularly in subduction zones");

> "Very large earthquakes occur on fault areas where the slope is the most regular, or flat." The Cascadia fault … lies along such a flat region, [noted] Rempel and Thomas… [and] Thomas said… "When Cascadia goes, it could be 1,000 kilometers (621 miles) if it ruptures completely."

Press Release, EUREKALERT!, *Fault Curvature May Control Where Big Quakes Occur* (Nov. 24, 2016), https://www.eurekalert.org/pub_releases/2016-11/uoo-fcm112216.php.

3. A. C. Pigou, discussing the tendency in economic exchange to discount rewards over time:

> Generally speaking, everybody prefers present pleasures or satisfactions of a given magnitude to future pleasures or satisfactions of equal magnitude, even when the

rational decisions, but are limited in their ability to do so by the context in which their decisions are made, their learning, and their beliefs about the choices before them.[4]

The following paragraphs explain how bounded rationality, interpreted as three sources of bias in capital investments over time, give rise to seismically vulnerable built environments. First, decisions made today are tempered by past investments in the built environment, though past investments were often made without regard to current known hazards in the landscape. Second, despite widespread general knowledge of the threat of earthquakes, the human propensity to disproportionately value short-term benefits over long-term gains creates an incentive for people to avoid the expenditures necessary to safeguard capital assets. Third, the presentation of hazards in the landscape as risks in the future exacerbates these problems by levying the human habit of absorbing risk with inadequate attention to the consequences. To make more lasting investments in the built environment we must guard against these sources of bias. This essay concludes by outlining simple capital planning remedies.

> latter are perfectly certain to occur. But this preference for present pleasures does not—the idea is self-contradictory—imply that a present pleasure of given magnitude is any *greater* than a future pleasure of the same magnitude. It implies only that our telescopic faculty is defective.

A. C. PIGOU, THE ECONOMICS OF WELFARE 24–25 (4th ed. 1932) (emphasis in original).

4. Herbert Simon discusses the empirical evidence of bounds on rationality yet to be incorporated in economic theories of decision-making:

> We already have in psychology a substantial body of empirically tested theory about the processes people actually use to make boundedly rational, or reasonable decisions. This body of theory asserts that the processes are sensitive to the complexity of decision-making contexts and to learning processes as well. The application of this procedural theory of rationality to economics requires extensive empirical research, much of it at micro-micro levels, to determine specifically how process is molded to context in actual economic environments and the consequences of this interaction for the economic outcomes of these processes.

Herbert Simon, *Rationality in Psychology and Economics*, 59 J. BUS. S209, S223 (1986); *See also* David Kahneman, *Maps of Bounded Rationality: Psychology for Behavioral Economics*, 93 AM. ECON. REV. 1449, 1449 (2003) ("Our research attempted to obtain a map of bounded rationality, by exploring the systematic biases that separate the beliefs that people have and the choices they make from the optimal beliefs and choices assumed in rational-agent models").

II. EARTHQUAKES TRANSFORM INVESTMENTS INTO LIABILITIES

Human settlements rarely stray from the historical path of prior investments because people use the economic and social success of past investments to guide the choices they make today.[5] Locational patterns of investment evolve from small historical events: from chance historical events, opportunities arise and grow into centers of commerce that attract and retain an expert labor force.[6] Seemingly small acts—such as the 1968 purchase of a computer at Seattle's Lakeside Middle School for a club that included 8th grader Bill Gates, Jr. and his subsequent access to computer labs at the University of Washington—can be thought of retrospectively as chance events on the path toward the formation of Microsoft, a pivotal entity in the evolution of technology and commerce in the greater Seattle region.[7] Such events form paths within the greater historical context of the educational institutions, infrastructure investments, resource-based industries, and ports of trade that have served the Puget Sound.[8] Reinforced by existing development patterns, decisions about where to build mark attempts to gain increasing returns from existing infrastructure, services, and associated economic conditions, such as opportunities for education, employment, and return on investment.[9]

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5. *See* Brian Arthur, *Positive Feedbacks in the Economy*, SCI. AM., Feb. 1990, at 92–99; For a more general treatment of the economics of geography, *see generally* MASAHISA FUJITA ET AL., THE SPATIAL ECONOMY: CITIES, REGIONS, AND INTERNATIONAL TRADE (1999).

6. *See* Arthur, *supra* note 5, at 92–99.

7. Quoting Bill Gates Jr. on the time when he first began to program computers,

> "It was my obsession" Gates says of his early high school years. "I skipped athletics. I went up there at night. We were programming on weekends. It would be a rare week that we wouldn't get twenty or thirty hours in. There was a period where Paul Allen and I got in trouble for stealing a bunch of passwords and crashing the system. We got kicked out. I didn't get to use the computer the whole summer. This is when I was fifteen and sixteen. Then I found out Paul had found a computer that was free at the University of Washington. They had these machines in the medical center and the physics department. They were on a twenty-four-hour schedule, but with this big slack period, so that between three and six in the morning they never scheduled anything." Gates laughed. "I'd leave at night, after my bedtime. I could walk up to the University of Washington from my house, or I'd take the bus. That's why I'm always so generous to the University of Washington, because they let me steal so much computer time."

MALCOLM GLADWELL, OUTLIERS: THE STORY OF SUCCESS 52–53 (2008).

8. *See generally* PLANNING THE PACIFIC NORTHWEST (Jill Sterrett et al. eds., 2015).

9. *See* Arthur, *supra* note 5, at 92–99.

The historical path-dependence of human settlements may appear to be more of a liability than a benefit, however, when juxtaposed against the advancing science of earthquakes. The science of extreme events is relatively new to the scene of human settlement. The population of the Puget Sound had already reached about 500,000 by 1915, when Alfred Wegener published evidence for the theory of continental drift in *The Origin of Continents and Oceans*.[10] Wegener's publication sparked a debate that was not settled until the 1960s after the discovery of oceanic ridges and trenches and the role of subduction in making the Pacific Rim into a "ring of fire"—where earthquakes 9.0 or greater in magnitude are known to occur.[11] Scientists were aware that the Juan de Fuca plate was sliding beneath the coastline of the Pacific Northwest, creating the Cascadia Subduction Zone, yet were still unaware of any earthquakes caused by this motion.[12] It was not until the 1990s—after the Puget Sound surpassed 2.5 million residents—that historical evidence of a 9.0 earthquake on January 26, 1700 was pieced together, and scientists began in earnest to understand the vulnerability of this region to earthquakes.[13] Since then, a 2012 analysis has confirmed that the region experienced nineteen earthquakes along the length of the subduction zone over the past 10,000 years, ranging in magnitude from 8.7 to 9.2.[14] A more recent study suggests, on

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10. For historic population estimates, *see* Tom Trimbath, *Seattle, King County and Puget Sound Keep on Growing*, CURBED SEATTLE (JULY 14, 2016, 8:00 AM), http://seattle.curbed.com/2016/7/14/12179970/seattle-king-county-puget-sound-growth-population; *Plate Tectonics: The Rocky History of an Idea,* U. OF CAL. MUSEUM OF PALEONTOLOGY, http://www.ucmp.berkeley.edu/geology/techist.html (last visited May 13, 2017) (citing ALFRED WEGENER, THE ORIGIN OF CONTINENTS AND OCEANS (John Biram trans., 1915)).

11. *See Plate Tectonics: The Rocky History of an Idea*, *supra* note 10.

12. Kathryn Schulz, *The Really Big One*, THE NEW YORKER (July 20, 2015), http://www.newyorker.com/magazine/2015/07/20/the-really-big-one; Robert Yates discusses the emergence of the science in Chapter 4 of his book, *Living with Earthquakes in the Pacific Northwest*. ROBERT YEATS, LIVING WITH EARTHQUAKES IN THE PACIFIC NORTHWEST 61–90 (Oregon State University Press eds., 2004) http://oregonstate.edu/instruct/oer/earthquake/index.html (ebook).

13. Schulz, *supra* note 12; Yeats, *supra* note 12, at 61–90; Trimbath, *supra* note 10.

14. In a press release from Oregon State University, lead researcher Chris Goldfinger described the findings:

> "Over the past 10,000 years, there have been 19 earthquakes that extended along most of the margin, stretching from southern Vancouver Island to the Oregon-California border," Goldfinger noted. "These would typically be of a magnitude from about 8.7 to 9.2 – really huge earthquakes. We've also determined that there

average, a recurrence interval of 430 years for quakes of this size, though the time between events has been as low as 100 to 300 years.[15] This is not welcome news to the Puget Sound. The region is approaching four million residents with no sign of slowing; much of this growth is in the vulnerable area west of the peaks of the Cascade Range, in the vicinity of Interstate-5.[16] When considering the possible effect of a 9.0 earthquake across Western Washington today, an estimated 5.4 million people are at risk.[17]

This 200-year mismatch of timing between human settlement of Puget Sound and the science of earthquakes has profound implications. These scientific discoveries threaten to transform the physical assets of the entire region into liabilities. People have made capital investments seeking increasing returns, but investments made without knowledge of vulnerability and fortification against damage through siting, design, and construction, may be nothing more than sunk costs. People may not realize the extent to which their

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have been 22 additional earthquakes that involved just the southern end of the fault," he added. "We are assuming that these are slightly smaller – more like 8.0 – but not necessarily. They were still very large earthquakes that if they happened today could have a devastating impact."

Mark Floyd, *13-Year Cascadia Study Complete – And Earthquake Risk Looms Large*, OR. ST. U. (Aug. 1, 2012), http://oregonstate.edu/ua/ncs/archives/2012/jul/13-year-cascadia-study-complete-%E2%80%93-and-earthquake-risk-looms-large.

15. Kale Williams, *Risk of Major Quake on Cascadia Subduction Zone Higher than Previously Thought*, THE OREGONIAN (Aug. 19, 2016, 10:57 AM), http://www.oregonlive.com/pacific-northwest-news/index.ssf/2016/08/risk_of_major_quake_on_cascadi.html ("The northernmost section [of the Cascadia Subduction Zone], from Astoria [Oregon] to Vancouver Island in British Columbia, had its quake frequency revised down from an earthquake every 500 to 530 years down to one every 430 years"); *History of Earthquakes in Cascadia*, CASCADIA REGIONAL EARTHQUAKE WORKGROUP http://www.crew.org/earthquake-information/history-of-earthquakes-in-cascadia, ("Scientists believe the most recent subduction zone earthquake, a M9 event, occurred in January 1700. . . . the years between these events have been as few as 100 to 300 years") (last visited June 11, 2017); *see also* Haas, *supra* note 1 (graph of "Cascadia Earthquake Time Line").

16. *See* Trimbath, *supra* note 10 (discussing population growth in the Puget Sound); Gary Lettman et al., *Protecting Working Farm and Forest Landscapes: How Do Oregon and Washington Compare?*, *in* PLANNING THE PACIFIC NORTHWEST 51 (Jill Sterrett et al. eds., 2015) (noting land use change and population growth west of the Cascade Range from 1974 to 2009 during which "[a]pproximately 90 percent of the development of private land in western Oregon and Washington occurred within 30 miles of Interstate 5").

17. Sandi Doughton et al., *Seismic Neglect: The Earthquake Nightmare Public Officials are Failing to Confront*, THE SEATTLE TIMES (May 14, 2016), http://projects.seattletimes.com/2016/seismic-neglect/.

investments have devolved into sunk costs until disaster strikes, when they are forced to weigh the full value of losses against the benefits they had hoped to obtain. The population of the Puget Sound and greater Cascadia region is at risk because the built environment is mainly comprised of structures that were not designed to withstand an earthquake with a magnitude of 9.0.

III. GENERAL THREATS OF EARTHQUAKE OFFER INADEQUATE COUNSEL

Despite current knowledge of earthquakes, people struggle to visualize the future effects of such hazards on existing facilities.[18] The vulnerability of capital assets to earthquakes is not common knowledge; it is specialized knowledge in engineering. Vulnerability can persist despite evidence of earthquake risk because bias in favor of present-day rewards gives momentum to developers in real estate who speculate in land, develop properties, and sell to the highest bidder, and who may continue to profit as they impart risk to the persons who purchase and occupy the property. Developers retain the expertise necessary to comply with protective seismic codes for buildings and construction, if policymakers are willing to impose this requirement. Regardless, the people who ultimately purchase property may be aware that the region suffers from earthquakes, but are not likely to have specialized knowledge of the vulnerability of individual properties to earthquakes.

In the absence of specialized knowledge, people make capital investments according to preferences in settlement patterns that appear rational, such as the choice of a home in proximity to employers and family, but also subject to biases in decision-making that appear less rational. In general, people are more emotional about the investments they make than one might

18. Nate Berg, *When, Not if: How Do San Franciscans Live with the Threat of the Next Quake?*, THE GUARDIAN (March 27, 2014, 4:00 PM), https://www.theguardian.com/cities/2014/mar/27/san-francisco-live-constant-risk-next-major-quake#img-4 ("Earthquakes are just one example of how we all have a problem with risks that are very infrequent, low probability, despite their high consequence . . . . Cities around the world are exposed to a variety of low-likelihood but high-consequence events, and because of our psychological nature, we're not very good at assessing the risks").

imagine from economic descriptions of rational actors.[19] For example, the fear of loss is more powerful than gain, and this tendency can support decisions that maintain the status quo, even if this leads people to "throw good money after bad."[20] People also use information that is easy to access when making decisions and may passively accept risks if those risks, such as earthquakes, are not highly regarded in the environment or "framework" of the decision to be made.[21] People rely on intuition to set a frame for decisions: they may assume that a building is safe because a public authority granted a permit, even though the permit was granted prior to the local discovery of vulnerability to earthquake. Such limitations are not alleviated when investing in a capital asset such as a house, even though a house is likely to be the most expensive investment a person will make.[22] Social desires for conformity and bandwagon effects, in addition to cost or price, can override the concern people may otherwise have for choosing safe locations, selecting safe designs for development, investing in seismic retrofits and insurance, and becoming prepared for earthquakes.[23] Experience, good information, and prompt feedback are important factors that assist people in

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19. *See generally* KAHNEMAN, *supra* note 4.

20. *See, e.g.*, William Samuelson & Richard Zeckhauser, *Status Quo Bias in Decision Making*, 1 J. RISK & UNCERTAINTY 7 (1988); Richard H. Thaler, *Mental Accounting Matters*, 12 J. BEHAV. DECISION MAKING 183 (1999).

21. *See* KAHNEMAN, *supra* note 4, at 1459–60. Kahneman concludes that:

> [P]eople's views of decisions and outcomes are normally characterized by 'narrow framing' . . . . [D]ecisions made in narrow frames depart far more from risk neutrality than decisions that are made in a more inclusive context. The prevalence of narrow frames is an effect of accessibility [of salient information] . . . . Narrow frames generally reflect the structure of the environment in which decisions are made. The choices that people face arise one at a time, and the principle of passive acceptance suggests that they will be considered as they arise. The problem at hand and the immediate consequences of the choice will be far more accessible than all other considerations, and as a result decision problems will be framed far more narrowly than the rational model assumes.

Id.

22. *Id.* at 1468–69 ("A growing literature of field research and field experiments documents large and systematic mistakes in some of the most consequential financial decisions that people make, including . . . actions in the real estate market.") (citing David Genesove & Christopher J. Mayer, *Loss Aversion and Seller Behavior: Evidence from the Housing Market*, 116 Q. J. ECON. 1233 (2001)).

23. *See* KATHLEEN TIERNEY, THE SOCIAL ROOTS OF RISK: PRODUCING DISASTERS, PROMOTING RESILIENCE 48 (Karlene H. Roberts & Ian I. Mitroff eds., 2014) (discussing the sociological origins of development at risk of disaster and institutional inertia, including bandwagon effects and conformity amongst consumers).

making good decisions, but none of these characteristics are currently available to people as they place themselves and their assets at risk of mega-earthquakes in the Cascade Subduction Zone.[24]

IV. RISKS TODAY BECOME INVESTMENTS TO BE MADE TOMORROW

For local government planners, architects, engineers, and financial officers contemplating the next capital investment or permit, standard methods of assessing the value and risk of loss are not helpful in raising awareness of actual vulnerability. A two-fold problem is created by methods used to value assets in the future through discounting and to communicate the risk of extreme events. Discount rates, as applied in cost-benefit analyses, were invented to express the bias humans have for present expenditures over future savings.[25] Applied to capital investments, however, discounting can result in severe problems, as durable assets appear to be disproportionately less appealing than short-lived assets with early returns on investment.[26] Discount rates that reward

24. *See* RICHARD H. THALER & CASS R. SUNSTEIN, NUDGE: IMPROVING DECISIONS ABOUT HEALTH, WEALTH, AND HAPPINESS 72 (2008) ("In many areas, ordinary consumers are novices, interacting in a world inhabited by experienced professionals trying to sell them things. More generally, how well people choose is an empirical question, one whose answer is likely to vary across domains. It seems reasonable to say that people make good choices in contexts in which they have experience, good information, and prompt feedback . . . . They do less well in contexts in which they are inexperienced and poorly informed, and in which feedback is slow or infrequent").

25. *See generally* Shane Frederick et al., *Time Discounting and Time Preference: A Critical Review*, 40 J. ECON. LITERATURE 351 (2002) (reviewing the origins, assumptions, and inadequacies, of the discounted utility model of intertemporal decision-making).

26. Carl Koopmans & Piet Rietvold, *Long-term Impacts of Mega-projects: The Discount Rate*, *in* INTERNATIONAL HANDBOOK ON MEGA-PROJECTS 314–15 (Hugo Priemus & Bert van Wee eds., 2013). Koopmans and Rietvold explain that although it is common to use discount rates derived from capital markets, "measured by means of the interest rate on government bonds" in capital investments, when doing so, "rates derived from financial decisions on a time scale of at most a few decades may be applied to benefits and costs that occur over (much) longer periods, affecting future generations" and that, critically, this approach assumes "that welfare can be freely (re)distributed among generations within a country" such that if the current generation invests in a facility to benefit future generations in one respect, it "might reduce its endowments to future generations in other respects." *Id.* The exhaustion of resources by current generations without compensation violates this assumption, and the widespread unsustainable use of natural resources without compensation explains how inequities arise from referencing capital markets when setting discount rates on

short-term investments dissuade people from making expenditures in seismic safety, which would improve value over the long-term. Risk is understood as exposure to danger, but it is often expressed as the probability that an event of a given magnitude will occur in a given timeframe.[27] While probability is a scientifically meaningful concept, it does not translate well into the policy environment of extreme future hazards. Placed up against the propensity to spend for short-term gain, estimates of the probability of an extreme event can give people the illusion of safety, a loophole for those who have other needs that they would prefer to prioritize. The presentation of risk as the probability that an event will occur, together with a bias for expenditures that earn present instead of future value, produce the specter of an endless loop of studies without decisive action about the problem of earthquakes.[28]

V. CONCLUSION: TO SAFEGUARD INVESTMENTS, INTERNALIZE THE EXTERNALITY

The conundrum for earthquake-safe capital investment created by these biases and distortions in decision-making will require many problem-solving efforts, but the starting point is relatively simple. Decision-makers should be provided with the estimated financial losses to their buildings and infrastructure should an extreme event occur today, based on the reconstruction or rehabilitation costs of existing and proposed capital assets, shown in nominal values (i.e., current prices).[29] This is specialized knowledge that people currently lack when weighing, or framing, their capital investment decisions.

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durable capital investments. *Id.* Similarly, capital investments made without regard to impending future losses from earthquake violate this assumption, posing what may be severe problems of intergenerational equity. *Id.*

27. *Cf. Your Earthquake Risk*, FEMA, https://www.fema.gov/your-earthquake-risk (last visited May 11, 2017) ("Three main factors together determine seismic risks: the level of seismic hazard, the number of people and amount of property that are exposed to seismic hazards and how vulnerable these people and property are to the hazards.").

28. *See, e.g.*, Daniel Gilbert & Sandi Doughton, *Washington's 30-Year Earthquake Drill for the 'Big One': Order Studies. Ignore Them. Repeat.*, THE SEATTLE TIMES (Jan. 27, 2017, 6:00 AM), http://www.seattletimes.com/seattle-news/northwest/washington-30-year-earthquake-drill-for-big-one-order-studies-ignore-them-repeat/; Doughton, *supra* note 17.

29. Displaying future costs in nominal values is the functional equivalent of using a zero discount rate.

Without this information, it is unlikely that the effects of an impending earthquake would be incorporated into their investment decisions.

In economic terms, extreme future events are externalities. They are generally not part of the deal that is made when a permit is granted or a capital asset is constructed. If protection against a hazard is not part of the price paid for a capital investment, then the hazard, real as it may be, is external to the transaction that brought about the capital investment. Making estimates of the damage or loss forecasted from earthquakes as plain to see as capital construction costs creates transparency for the externality, and provides a basis for discussion about the difficult trade-offs that the threat of a 9.0 earthquake brings to the residents of the region. Presented alongside the added cost of protecting a new asset with seismic reinforcement, forecasts of losses from earthquakes can motivate developers to internalize the externality within the design of buildings and infrastructure. Set against the cost to retrofit existing assets, such forecasts of loss serve as appropriate financial targets for capital investment across the region, even if such targets appear so large that it may only be possible to fill the gap incrementally over time. Forecasts of loss also describe in dollar values the benefits of regulatory changes in the long-term interest of residents, such as changes in building codes. Similarly, for the damages that remain unforeseen or unavoidable, they create a target for capital reserves that policymakers, businesses, homeowners, and other residents can begin to take into account. This is a difficult but necessary step. Catastrophe is expensive, yet the effort to avoid catastrophe also comes at a cost. The people of the Cascadia region will have to bear one or face the other.