# ECONOMIC ANALYSIS *of a* CASCADIA SUBDUCTION ZONE EARTHQUAKE

PORTLAND METROPOLITAN REGION I JULY 2020

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Other firms, agencies, and staff contributed to other research that this report relied on. That assistance notwithstanding, ECONorthwest is responsible for the content of this report. The staff at ECONorthwest prepared this report based on their general knowledge of urban, transportation, and natural resource planning, and on information derived from government agencies, private statistical services, the reports of others, interviews of individuals, and other sources believed to be reliable. ECONorthwest has not independently verified the accuracy of all such information and makes no representation regarding its accuracy or completeness. Any statements nonfactual in nature constitute the authors' current opinions, which may change as more information becomes available. ECONorthwest staff who contributed to this report include Joel Ainsworth, Marley Buckman, Melissa Carson, Adam Domanski, Laura Marshall, Sarah Reich, Mike Wilkerson, and Virginia Wiltshire-Gordon.

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A Cascadia Subduction Zone earthquake (CSZ event) poses risks to physical infrastructure throughout Oregon and beyond. Widespread physical destruction at predicted levels would disrupt human, social, and economic systems at a regional scale. The impact of these disruptions is expected to exceed the experience of most Oregonians, and would be unlike any disruption that businesses and government entities in the state have had to respond to in recent history.[1]

Earthquake-induced physical and economic disruption has the potential to change existing quality of life. Oregonians experience quality of life in many ways, and current and historical disparities in access to resources and lived experiences have created inequality. A CSZ event is likely to exacerbate these inequities by benefiting those who have the resources to respond and recover and further harming those who don't. The CSZ event could result in long-lasting changes that leave many Oregonians worse off. However, with sufficient preparation, the disruption could be reduced, providing opportunities for realignment and growth. How the CSZ event ultimately affects Oregon's economy largely depends on the capacity of individuals, households, businesses, and institutions to adapt through the sequence of shock, response, and recovery.

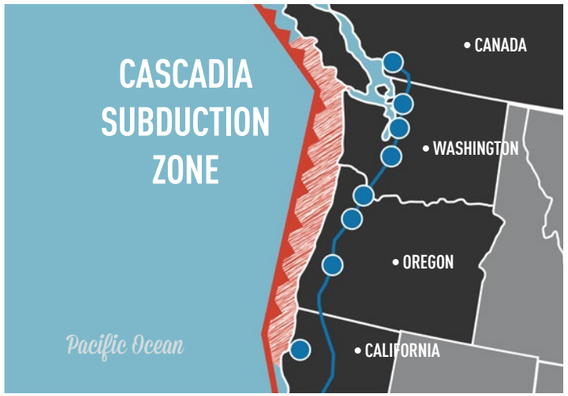
This study addresses how a CSZ event would disrupt the economy of the Portland Metropolitan Region. The Regional Disaster Preparedness Organization (RDPO) supported the work, which was guided by input from emergency managers representing local governments across the Portland region.

### Study Objectives

This study provides insights into the scope and scale of economic disruption in the Portland metro region following a CSZ event. It illustrates the sensitivity of the economy to different types of resilience interventions. Finally, it explores the distribution of economic effects across some populations who may experience impacts more than others.

### Intended Audience

This report is written for an audience of policy makers, planners, business owners, and individuals interested in understanding the economic impacts of a CSZ event. A separate Executive Summary and Presentation summarize key findings for the general public, decision makers, and others who may not want to read the entire report.




The information is intended to help the region's leaders and business owners begin to understand the economic implications of the CSZ event. With a more complete picture of the risks of disruption, leaders can better make the case for investments that will minimize economic disruption and shrink equity gaps following a CSZ event. Although this report does not recommend specific policies to enhance resilience, it makes the case that reducing inequality and preparing for CSZ-related impacts can yield dividends now and in the future.

## Purpose of This Study

This study builds on estimates the Oregon Department of Geology and Mineral Industries (DOGAMI) produced about the likely physical damage from a CSZ event in the Portland Metropolitan Region (Portland region).[2] Overlaying economic data spatially with DOGAMI's data describing physical damage, it takes a first step toward estimating the scale of economic disruption in the Portland region that would follow a CSZ event. It also illustrates the sensitivity of the economy to different resilience interventions that policy makers are considering to help minimize the disruptive effects of the CSZ event. Leaders and business owners in the Portland region can use the results of this study to support policies that reduce economic risk and vulnerability, and take steps to help economic recovery happen more rapidly and equitably after such an event.

The results of this study are intended to provide a high-level understanding of how economic systems might respond to a CSZ event. It is not a benefit-cost analysis of a particular policy, nor does it provide a set of recommendations for how the region can bolster economic resilience. By estimating potential disruption, revealing potential vulnerabilities, and testing business sensitivity to specific resilience interventions, this study lays the groundwork for future avenues of research. It provides business owners and public and private planners with a preliminary understanding of economic impacts, and suggests possible areas to focus ongoing planning efforts, invest in data development, and develop future research inquiries.

## Elements of This Study

This study focuses on economic disruption that would occur within the Portland region — Clackamas, Clark (WA), Columbia, Multnomah, and Washington Counties (*see map*) — along three interrelated dimensions:

1. Direct disruption to businesses, measured in terms of temporary closure;
2. Distribution of disruption across vulnerable populations; and
3. Regional economic disruption.

The report is organized around findings in each of these areas. The approach to assessing effects in each of these areas was informed by an initial literature review. The study benefited from input along the way from a regional stakeholder workgroup, made up of emergency management professionals representing jurisdictions across the Portland region.[3]

Additional perspectives were gathered from businesses, utility managers, and economic development organizations through a key-informant interview process.[4] Exhibit 1 shows the elements of the study and how they relate to each other.

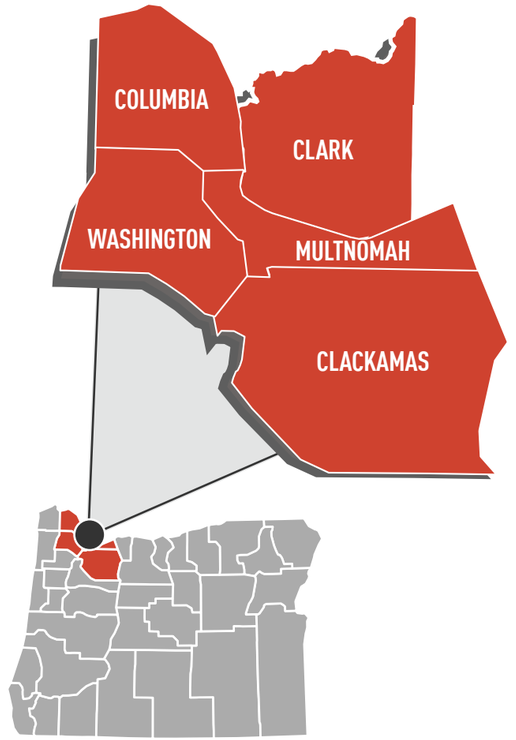
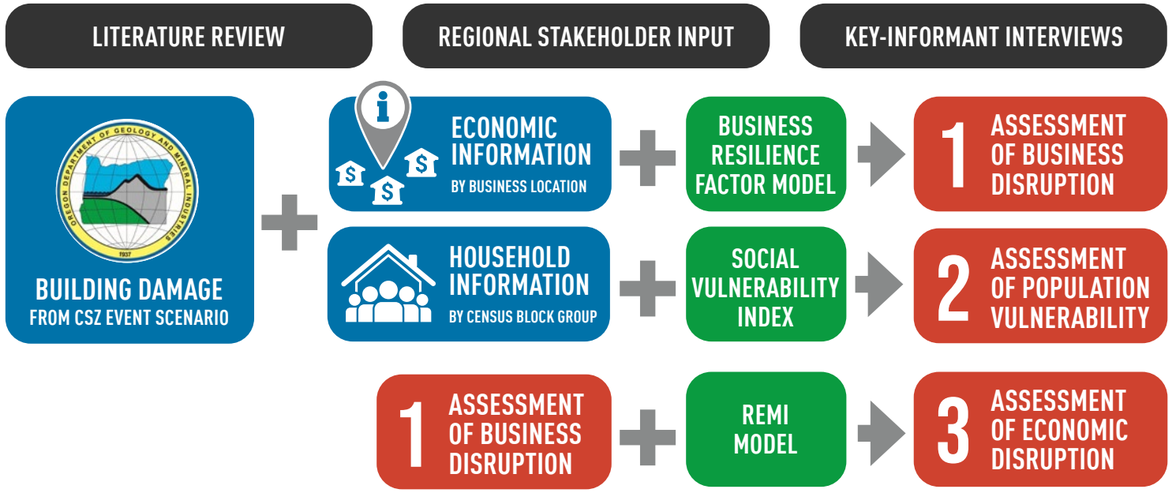



**EXHIBIT 1 STUDY ELEMENTS**




Source: ECONorthwest

[1] At the release of this report, the COVID-19 pandemic represents a disaster that continues to unfold with significant economic implications. It may provide insights into the capacity of the region to respond to economic disruptions arising from Cascadia, although the type of shock and available strategies for response and recovery are distinctly different. The last chapter of this report addresses the similarities and differences between COVID-19 and a CSZ event related to economic disruption and recovery.

[2] Bauer, J.M., W.J. Burns, and I.P. Madin. 2018. *Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon.* Department of Geology and Mineral Industries. Available at https://www.oregongeology.org/pubs/ofr/p-O-18-02.htm

[3] These participants are identified and recognized for their contribution at the beginning of this report.

[4] For confidentiality reasons, conversations with individual businesses are not included along with this study. However, feedback received is incorporated into the analysis and key insights are highlighted throughout this report.

### Literature Review

The study design and approach were informed by a survey of the literature. The literature addressing the economic effects of disasters is broad and extensive. It provides definitional structure, theoretical foundations, and empirical findings about how businesses and economies respond following all kinds of disasters.

**Section 2** of this report summarizes the literature in three broad categories that correspond to the analytical inquiries in this report: 1) Literature about business response to disaster events; 2) Literature about the disproportionate effects of disasters on businesses; and 3) Literature about how economies respond to disasters in the short and long term. The original literature review that guided early framing of the analysis presented in this report is reproduced in the Technical Appendix.

### Direct Disruption to Businesses

**Section 3** of this report addresses the question: **How would a CSZ event disrupt businesses in the Portland region?** The analysis merges firm-level data from the Quarterly Census of Wages and Employment (QCEW)[5] with parcel-level building damage estimates from DOGAMI. DOGAMI modeled physical disruption across multiple scenarios. This analysis relies on DOGAMI's damage estimates arising from a 9.0-magnitude earthquake along the Cascadia Subduction Zone fault during dry soil conditions. It assumes a single event occurs without potential compounding damage resulting from aftershocks.

Based on observations of business responses following disasters, economic activity doesn't stop after an event. Some businesses close temporarily while others continue operating,

Disaster relief for survivors of the Quito, Ecuador, earthquake in 2016. (Source: Shutterstock)

even if the physical structure a business operates from is damaged. Myriad factors influence this decision. To account for these factors, this analysis estimates business disruption using a statistical model derived from survey data identifying the factors that influenced a business's decision to close following previous natural disasters.

Building on the estimate of direct disruption to businesses, the analysis uses the statistical model to test how sensitive businesses are to improvements in infrastructure resilience. The analysis tests three interventions:

1. Reinforcing transportation networks;
2. Reducing disruptions to utility services; and
3. Retrofitting URMs

This part of the analysis suggests how sensitive the region's businesses might be to different investments that reduce disruption in certain areas. It also explores qualitatively how retaining population following an event (an effect that may occur if regional resilience is increased and fewer people decide to leave their homes and businesses) could affect economic recovery. It does not assess the cost-effectiveness of these interventions, so further economic and policy analysis should be conducted before making decisions based on these results.

### Distribution of Disruption Across Vulnerable Populations

**Section 4** of this report addresses the question: **How is CSZ event damage distributed among vulnerable populations in the Portland region?** This inquiry begins with DOGAMI's building damage estimates. It explores the spatial intersection between building damage and concentrations of population vulnerability. Using data from the U.S. Census, it also describes the relationships between vulnerable populations and business disruption.

This analysis helps to broaden the understanding of the region's capacity to initiate a robust economic recovery following the CSZ event. Vulnerable populations, including low-income families, ethnic and racial minorities, and others, are integral participants in the economy as business owners and workers. Their capacity to respond to and recover from disasters is often diminished because of limited access to capital and entrenched inequities, among other factors. This can hamper economic recovery by reducing the productive capacity of the labor force, and by underutilizing valuable

[5] Quarterly Census of Economics and Wages (QCEW) contains confidential information and was available for this study through a data use agreement with the Oregon Employment Department. All results are aggregated and reported in a way that maintains confidentiality standards.





Portland, Oregon (Source: Shutterstock)

creative resources. These results lay a foundation for further efforts to build capacity in and support these populations so they may fully participate in and benefit from economic recovery following a CSZ event.

### Regional Economic Disruption

Individual business disruption following the CSZ event would have ripple effects throughout the Portland region's economy. **Section 5** of this report addresses the question: **How would disruption to businesses across the Portland region affect the regional economy, and how would resilience interventions that reduce disruption change that effect?** To estimate change in the regional economy, estimates of changes in firm employment were aggregated to produce a weighted average of employment disruption in the Portland region. The employment estimates were then used as an input for the Regional Economic Models, Inc. (REMI) input-output model to build resilience scenarios and test how the economy would respond to changes in business disruption assumptions.

Economic impact models, such as REMI, measure the change in economic activity in a study region related to external events that result in a discernible change in demand. Typically, these studies trace the flow of regional spending across industries to measure changes in jobs, labor income, and gross regional product. A frequent criticism of these models is that they are misused to describe large (positive or negative) effects to a region's economy without the necessary context or relevant policy implications. On the other hand, when done thoughtfully, these analyses can help test the sensitivity of a region's economy from large economic shock, such as CSZ event.

Understanding how shocks in specific industries can affect other parts of the economy provides a useful context for decisions about preparedness and mitigation strategies with scarce resources. It is important to note that the underlying rationale for using an input-output model for this analysis is not to predict the loss in Gross Regional Product (GRP) after a CSZ event, but to test scenarios that can help inform policy decision making.

## Conclusions and Next Steps

The results of this study can be viewed as a starting point to answering more complex questions. The data set produced in this study by combining spatially referenced business data with DOGAMI's parcel-level building damage estimates is ripe for use in future research. **Section 6** outlines a set of follow-on research questions raised during the course of this study, but which the current project could not meaningfully address.

Finally, this report is being released at a time when the Portland region — along with the rest of the world — is confronting a different kind of disaster in the response to COVID-19. The alignment of these circumstances has provided an opportunity to reflect on how the current economic disruption is both like and unlike the kind of disruption that may occur at a regional scale following a CSZ event. **Section 6** highlights some of the parallels planners and policy makers can draw between the disasters to leverage insights from the current situation to help build economic resilience for a future CSZ event.

(Source: Shutterstock)

While the term "disaster" may evoke a range of imagery, it is defined on a regional scale as "an unforeseen event that causes great damage, destruction and human suffering, which overwhelms local capacity necessitating a national or international [response]."[6] Disasters are often categorized into three types:

1. **Natural** – e.g., floods, earthquakes, or epidemics;
2. **Technological** – e.g., industrial or transportation accidents; and
3. **Man-Made** – e.g., economic crises or wars.

Disasters are also defined on a temporal scale and can either be "slow-onset" disasters that emerge gradually over time (e.g., drought, sea-level rise, or epidemic disease) or "sudden-onset" disasters that are triggered by an event that occurs quickly and unexpectedly, such as an earthquake or critical infrastructure failure.[7]

The CSZ event falls into the category of a sudden-onset natural disaster. In an essay responding to the aftermath of Hurricane Katrina, Neil Smith, a Professor of Anthropology and Geography, famously pointed out that "there's no such thing as a natural disaster."[8] When natural phenomena, such as an earthquake, shock a region, the dimensions of the disaster that ultimately unfolds depend on the level of exposure, vulnerability, and capacity to respond within the affected human communities. With sufficient knowledge, resources, and political will, communities can make choices and investments that can transform a potentially devastating natural hazard event with a *disastrous* human and economic toll into a disruptive event with minimal lasting consequences for the people living through it.

This section summarizes the literature in three areas relevant to understanding the economic dimensions of natural hazards:

- Natural hazards and economic disruption
- Natural hazards and business disruption
- Dynamic responses to business and economic disruption

## Natural Hazards and Economic Disruption

Research has consistently revealed that economies are usually resilient when disrupted by a natural hazard event. Economic impacts at a regional or national scale are generally measured by changes in economic productivity. At the national scale, this is measured by gross domestic product (GDP). A global evaluation of natural and man-made disasters occurring from 1968-2001 found that disasters generate negative short-run impacts; however, over time, they result in a positive effect on per capita GDP — these results are summarized in Exhibit 2.[9] Additional studies have confirmed this finding, with the caveat that a disaster reinforces existing trends in the country.[10] In the case of the 1995 earthquake in Kobe, Japan, a lagging economic recovery continued the region's declining growth pattern.[11]

### EXHIBIT 2 EFFECTS OF DISASTERS ON PER CAPITA GDP
(ANNUAL RATE)

| | SHORT TERM (1 Year) | LONG TERM (20 Years) |
|---|---|---|
| Natural Disasters | -1 to -0.7% | +0.6 to +1.2% |
| Conflicts and Wars | -0.5 to -0.4% | +0.4 to +0.95% |
| Economic Crises | -0.4 to -0.2% | -0.5 to 0% |

Source: Sawada 2011

While the impact of disasters may not be significant in either the short term or the long term when measured at a national level, regional and local effects may be more impactful. Other work that studied the universe of natural disasters that struck the United States between 1920 and 2010 "a data set that included more than 10,000 disasters" found that counties hit with severe disasters experienced lasting (decadal) adverse economic effects, including greater population out-migration, lower home prices, and higher poverty rates.[12] These effects persist even after the economy has absorbed all private and government response aid, including new infrastructure investments.

Evaluations of disaster-related economic impacts on local governments have found that those in better financial condition (e.g., liquidity and solvency) before a natural hazard experienced a greater relative decrease in fiscal health than those with weaker initial status. This could indicate that the latter receives greater financial support from state and federal entities, while financially stronger local governments may use their own funds to manage disaster response.[13] Following the 2005 hurricane season, most of the local county and parish governments in Mississippi and Louisiana did not see significant changes in fiscal health, except those experiencing high physical hurricane damage. The authors concluded that federal assistance was important in buffering the disaster's shock to local governments, but it may not have been a reliable "insurer of last resort."[14]

Public-sector spending has generally been resilient to natural disasters. An evaluation of the financial shock of disasters at the state level from 1970-2013 found that when a state's total disaster damage exceeded 1 percent of its share of the gross state product (GSP), state government spending increased by 0.2 percent (share of GSP) and federal transfers increased by 0.27 percent (share of GSP) cumulatively in the five years following.[15] The study found that natural disasters caused a statistically significant negative shock to property and income tax revenues over a five-year period following the disaster. The effect on sales taxes was mixed, with increases associated with post-disaster recovery spending, but declines in sales tax collections over the five-year period offsetting the initial increase, for a net neutral effect. The results of this study suggest that tax revenues following disasters decline in the aggregate, and disaster spending at the state level is financed through federal transfers.

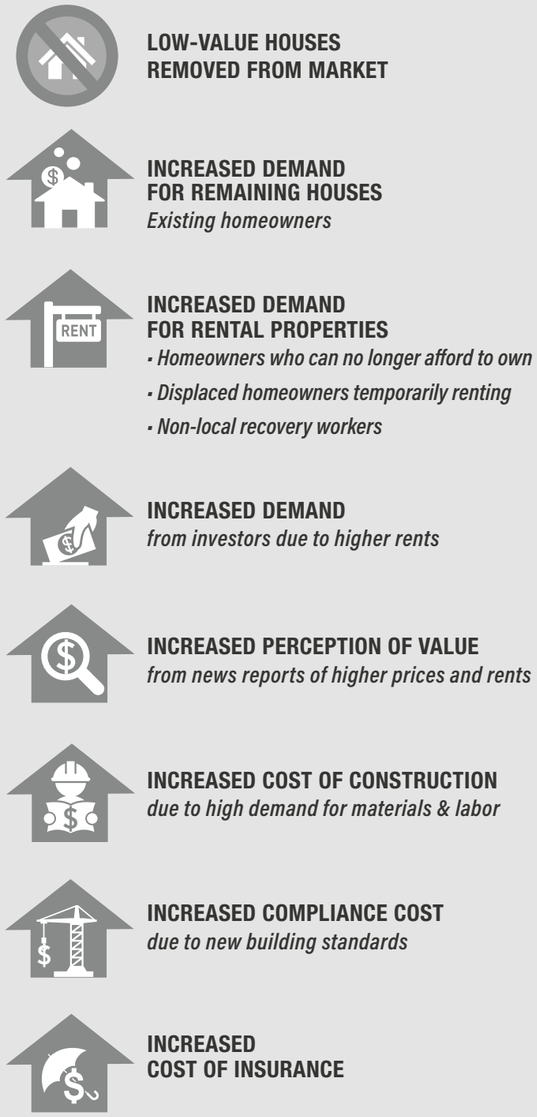
Labor market disruptions and economic output are common measures of household-level disaster response. Changes in population and property values can be viewed as indicators of household resilience to disasters. A county-level analysis of disasters from 1920-2010 found that increased frequency of these events led to growth in out-migration.[16] The strongest migration responses were observed with volcanoes, hurricanes, forest fires, and "super-severe disasters" (with 100 deaths or more). Net out-migration following these events increased by 3 percentage points, similar in scale to out-migration expected after a large negative employment shock.

The effect of large natural disasters on housing stock and prices shows that both shocks to supply and demand can affect the market in opposite directions. The net effect following a disaster is the result of both pre-disaster housing market conditions, and the magnitude of disaster-related changes in supply and demand. Boustan et al.'s analysis using 100 years of data on natural disasters at the county level found that repeat disasters have no effect on housing prices and rents, but super-severe disasters lower housing prices by 6 percent and rents by 3 percent. This effect is largely associated with increased out-migration associated with this category of disaster. In disasters that destroy a large portion of the housing stock, the effect on housing prices is ambiguous.[17]

Disasters that destroy existing housing stock, particularly in areas already experiencing housing market challenges, may deepen affordability challenges. The Canterbury earthquakes in 2010-2011 hit Christchurch, NZ, when it was already struggling with a housing affordability crisis. Substantial damage to the housing stock depressed an already tight supply, while demand for the remaining housing stock increased as displaced residents and non-local recovery workers competed to find local accommodations. Moreover, people seeking temporary housing during repairs — often paid for with insurance payouts — bid up rents, leading to higher returns for rental properties and increased market activity from property investors. In some neighborhoods, rents increased by almost 40 percent in the years following the earthquakes.[18] This alignment of market conditions led to substantial displacement and increasing inequality among property owners and tenants. Exhibit 3 summarizes the many factors at play following the 2010-2011 earthquakes that led to compounding unaffordability in the Christchurch housing market.[19]

[6] Sawada, Yasuyuki, Rima Bhattcharyay, and Tomoaki Kotera. et al. 2011. "Aggregate impacts of natural and man-made disasters: A quantitative comparison." RIETI Discussion Paper Series 11-E-023. Japan: The Research Institute of Economy, Trade and Industry.
[7] UNDRR. 2009. "UNISDR Terminology on Disaster Risk Reduction." United Nations Office of Disaster Risk Reduction.
[8] Smith, N. 2006. "There's no such thing as a natural disaster." Items. Social Science Research Council. June 11. Retrieved May 21, 2020, from https://items.ssrc.org/understanding-katrina/theres-no-such-thing-as-a-natural-disaster/
[9] Sawada, Yasuyuki, Rima Bhattcharyay, and Tomoaki Kotera. et al. 2011. "Aggregate impacts of natural and man-made disasters: A quantitative comparison." RIETI Discussion Paper Series 11-E-023. Japan: The Research Institute of Economy, Trade and Industry.
[10] Whitman, Z., Stevenson, J., Kachali, H., Seville, E., Vargo, J., & Wilson, T. (2014), Organisational resilience following the Darfield earthquake of 2010. Disasters, 38, 148–177. 10.1111/disa.12036
[11] Cavallo et al. (2010).; Chang (2010).
[12] Boustan, L.P., Kahn, M.E., Rhode, P.W., & Yanguas, M. L. (2017). The Effect of Natural Disasters on Economic Activity in US Counties: A Century of Data. Cambridge, MA: National Bureau of Economic Research. Retrieved from: http://www.nber.org/papers/w23410
[13] Fannin, J.M., Barreca, J.D., & Detre, J.D. (2011). The Role of Public Wealth in Recovery and Resiliency to Natural Disasters in Rural Communities. American Journal of Agricultural Economics, 94(2), 549-555. https://doi.org/10.1093/ajae/aar068
[14] Ibid.
[15] Miao, Q., Y. Hou, and M. Abrigo. (2018). "Measuring the Financial Shocks of Disasters: A Panel Study of U.S. States." National Tax Journal 71(1): 11-44.
[16] Boustan, L.P., M.E.Kahn, P.W. Rhode, and M.L. Yanguas. (2017). *The Effect of Natural Disasters on Economic Activity in U.S. Counties: A Century of Data.* National Bureau of Economic Research. Working Paper No. 23410. May.
[17] Ibid.
[18] Chang-Richards, Y., S. Wilkinson, E. Seville, and D. Brundson. (2014). "Housing the Workforce Following the Canterbury Earthquakes in New Zealand." *10th International Conference of the International Institute for Infrastructure Resilience and Reconstruction.* May 20-22. 135-140.
[19] McDonagh, J. (No Date). *Housing Affordability in Post-Earthquake Christchurch.* Available from http://www.prres.net/papers/Mcdonagh_Housing_%20Affordability_%20in_Post_Earthquake_Christchurch.pdf

## EXHIBIT 3
### MARKET FACTORS THAT LED TO HOUSING PRICE INCREASES IN CHRISTCHURCH




Both depressed housing prices and dramatic increases in housing prices and rents following disasters can contribute to higher levels of poverty and wealth inequality. Boustan et al. found that depressed housing prices and population out-migration — particularly among people with the financial and social resources to relocate — combined with in-migration of lower-income populations in response to declining housing prices may contribute to increased levels of poverty after super-severe disasters.[20] The compounding housing affordability crisis in Christchurch led to an erosion of wealth among more vulnerable segments of the population and among renters.

***Research demonstrates that, although national economies are resilient to disasters, as measured by short- and long-run changes in GDP, adverse effects on local and regional economies can be more pervasive. Without federal spending offsetting reductions in local revenue, local and regional effects could be more negative and persistent. Moreover, disasters tend to increase wealth inequality and exacerbate pre-existing market failures, especially in housing markets. Regional and local economies may suffer net long-term adverse effects in the form of population out-migration, lower housing prices, and higher levels of poverty.***

A longitudinal investigation of natural hazard impacts on wealth inequality in counties across the United States provides nuance to these findings. It found that in counties that experienced a costly natural disaster, on average and controlling for multiple variables, average wealth increased over a 15-year period following the disaster compared to counties that experienced more mild disasters. However, this trend only held for only white populations: non-white populations consistently lost wealth. Similarly, homeowners' wealth actually increased with local hazard damages over time, while renters lost wealth compared with renters in areas less affected by natural disasters.[21]

## Natural Hazards and Business Disruption

Businesses response to natural hazards is widely variable. They are affected both directly from a hazard event (e.g., direct damage and loss of life or property) and indirectly (e.g., changes in demand and revenue, or disruptions in supply chains).[23] Factors influencing business recovery range well beyond physical impacts, and include subsequent impacts on

[20] Boustan et al. 2017.
[21] Howell, J. and J.R. Elliott. (2018). "Damages Done: The Longitudinal Impacts of Natural Hazards on Wealth Inequality in the United States." *Social Problems* 66(3): 448–467.
[23] Chang, S.E., & Falit-Baiamonte, A. (2002). Disaster vulnerability of businesses in the 2001 Nisqually earthquake. Global Environmental Change Part B: Environmental Hazards, 4(2), 59-71.






Christchurch Cathedral showing the effects of the February 2011 earthquake. (Source: Wikipedia)

operations, and industry and neighborhood-level impacts.[24] Research has found that business impact and recovery is not always linear over time: Effects may show up immediately, or manifest months or years after an event.[25]

A body of empirical research has developed over the last 30 years to identify factors that influence the response and recovery trajectory of businesses and organizations. This work rests on extensive surveys of businesses following natural disasters, including hurricanes, floods, and earthquakes. From these surveys, researchers have identified a list of factors that influence the probability of a business's ultimate recovery or relocation. From these survey data, a few researchers have developed statistical models that may be used to predict recovery and understand factors that help recovery.[26]

Studies evaluating Hurricane Andrew in Florida, the Loma Prieta and Northridge Earthquakes in California, and floods in Des Moines, Iowa, found key pre-disaster indicators that influence or predict business survival.[27] Factors identified include business demographics, level of preparedness or resilience, financial health, and receipt of post-disaster assistance.

Other studies on firm resilience have shown that disasters tend to intensify pre-existing structural inequalities in businesses.[28] For example, the age, gender, and race of the business owner influence access to capital, a key vulnerability indicator. Other factors, such as veteran status and repeated exposures to adversity, also serve as indicators of firm recovery.[29] Notably, direct physical damage is not necessarily an indicator of firm survival, but rather the availability of lifeline services exhibits stronger influence on long-term viability.[30]

Other works have identified four categories of vulnerability that influence the degree of impact a business may experience following an environmental disaster.[31] The vulnerability categories include capital vulnerability, labor vulnerability, supplier vulnerability, and customer vulnerability.

### Access to Capital

Firm size is widely cited as a key determinant of business resiliency. Small businesses tend to be less prepared for disasters in comparison to larger firms. The number of employees in a business has a strong relationship to a firm's degree of disaster evacuation planning.[34] Additionally, smaller businesses tend to occupy riskier structures, concentrate in retail and service sectors, have smaller cash reserves, and are less likely to distribute risk through insurance against property damage and business interruptions.[26,28]

Following a disaster, a firm's location and mobility influence its recovery. Firms that lease office space are less likely to invest in mitigation actions and may operate in riskier physical structures. During the recovery process, these firms are dependent on the property owner for repairs, leading to uncertainty in the recovery timeline.[34] Capital- or technology-intensive industries are also at greater risk because of reduced mobility following a disaster.[32,33]

Franchises or firms with a number of different locations are able to mitigate risk across a broader geographic region and can provide continued operations in recovery.[32] A comparison

[24] Dahlhamer, JM., & Tierney, KJ. (1998). Rebounding from disruptive events: Business recovery following the Northridge earthquake. Sociological Spectrum, 18(2), 121-141.
[25] Webb, G.R., Tierney, K.J., & Dahlhamer, J.M. (2002). Predicting long-term business recovery from disaster: a comparison of the Loma Prieta earthquake and Hurricane Andrew. Global Environmental Change Part B: Environmental Hazards, 4(2-3), 45-58.; Tierney, K.J. (2007). Businesses and Disasters: Vulnerability, Impacts, and Recovery. Handbooks of Disaster Research, 275-296.
[26] Wasileski, G., H. Rodruguez, & W. Diaz (2011). Business closure and relocation: a comparative analysis of the Loma Prieta earthquake and Hurricane Andrew. Disasters. 2011, 35(1): 102—129.; Brown, C., Seville, E., Hatton, T., et al. 2019. "Accounting for Business Adaptations in Economic Disruption Models. *Journal of Infrastructure Systems* 25(1).
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[31] Zhang, Y., Lindell, M.K., & C.S. Prater. (2009). Vulnerability of community businesses to environmental disasters. Disasters, 33(1), 38-57. https://doi.org/10.1111/j.1467-7717.2008.01061
[32] Tierney, K.J. (1997). "Business Impacts of the Northridge Earthquake." *Journal of Contingencies and Crisis Management.* 5(2): 87–97.
[33] Whitman, Z., Stevenson, J., Kachali, H., Seville, E., Vargo, J., & Wilson, T. (2014), Organizational resilience following the Darfield earthquake of 2010. Disasters, 38, 148–177. 10.1111/disa.12036
[34] Marshall, M.I., L.S. Niehm, S.B. Sydnor, H.L. Schrank. (2015). "Predicting Small Business Demise After a Natural Disaster: An Analysis of Pre-Existing Conditions." *Natural Hazards* 79: 331-354.

of urban and rural firms found evidence that rural organizations are slightly more adaptable to varying conditions; however, their recovery is more directly related to changes in social capital and the restoration of the broader community).[33]

### Access to Labor

As a factor of production, employees are an important part of resiliency and firm recovery. A labor force that is unable to commute to work or is burdened with household-level recovery tasks is more disruptive to business recovery than physical damage.[32] Similarly, any relocations will decrease the labor workforce in disaster areas. Following Japan's Kobe earthquake in 1995, it took 10 years for population levels to recover.[36] Similarly, one year after Hurricane Katrina, the area had regained only half of its pre-disaster public transportation routes, 60 percent of its electricity customers, and had lost 30 percent of its labor force.[37]

Additionally, after Hurricane Katrina, vulnerable populations were slow to return to their previous neighborhoods, leading to a change in the demographic landscape of the region. Partly as a response to Hurricane Katrina, the Centers for Disease Control and Prevention (CDC) created the Social Vulnerability Index (SVI), which combines 15 census indicators to assist state, local, and tribal disaster management officials in identifying the locations of their most socially vulnerable populations. Estimated at the census tract level, the SVI can identify neighborhoods that have a limited capacity to anticipate, confront, repair, and recover from the effects of a disaster.[38]

A fallen water tower in Buras-Triumph, Louisiana, where Katrina made landfall. (Source: Wikipedia)

### Supply Chain Resilience

Similar to capital vulnerability, firm size influences a business's capacity to engage in mitigation actions such as excess capacity, surplus inventory, and redundant supply chains. Disaster damage to firm resources has an immediate impact on supply chain integrity outside of the disaster zone and total firm output.[39] Just like an economy, it takes time for a business to recover after a shock, and this newly stable state can be higher or lower than the old. Even when firms reach full operations at a pre-disaster level, they could have already lost market share.[40]

Governments play a major, yet indirect, role in supply chain integrity. Lifeline service disruption has been frequently mentioned in the literature and has a significant impact on business recovery. These disruptions are primarily outside the sphere of firm-level mitigation actions as they relate to public infrastructure and services. In response, preparedness measures at a government level should focus on maintaining the infrastructure networks that are key to household and firm recovery efforts.[41] Disaster management teams should also recognize how prioritization affects regional recovery. For example, during the New Zealand recovery efforts, the country prioritized densely populated areas for service restoration. As a result, there was a disproportional difference in business disruption in terms of rural operations versus urban firms.[42]

### Customer Base

The final factor of vulnerability is access to markets and customers' ability to engage in commerce. Resiliency indicators show that the degree of market diversification is important in business recovery.[43] Businesses that rely heavily on local markets are more heavily impacted because of the disaster's influence on consumer behavior.[44] For example, if a surrounding area is badly damaged, businesses reliant on foot traffic will be adversely affected. Similarly, single-location retail, finance, real estate, and service organizations also experience proportionally greater losses and have more difficulty recovering than businesses with diverse clientele. Resilience strategies, including alternative retail locations or government planning to enable pop-up space for early lifeline restoration, could improve small business recovery.[45]

[36] Chang, S.E. (2010). "Urban Disaster Recovery: A Measurement Framework and its Application to the 1995 Kobe Earthquake." Disasters, 2010, 34(2): 303–327.
[37] Ibid.
[38] Flanagan, B.E., Gregory, E.W., Hallisey, E.J., Heitgerd, J.L., & Lewis, B.L. (2011). A Social Vulnerability Index for Disaster Management. Journal of Homeland Security and Emergency Management, 8(1), 1-22. 10.2202/1547-7355.1792
[39] Gunessee, S., Nachiappan, S., & Kun, N. (2018). Natural disasters, PC supply chain and corporate performance. International Journal of Operations and Production Management, 38(1), 129-148.
[40] Sheffi, Y., & Rice, J.B. (2005). A Supply Chain View of the Resilient Enterprise. MIT Sloan Management Review, 47(1), 41-48.
[41] Tierney, K.J., & Nigg, J.M. (1995). Business Vulnerability To Disaster-Related Lifeline Disruption. Newark, DE: University of Delaware.
[42] Whitman, Z., Stevenson, J., Kachali, H., Seville, E., Vargo, J., & Wilson, T. (2014), Organisational resilience following the Darfield earthquake of 2010. Disasters, 38, 148–177. 10.1111/disa.12036
[43] Webb, G.R., Tierney, K.J., & Dahlhamerc, J.M. (2002). Predicting long-term business recovery from disaster: a comparison of the Loma Prieta earthquake and Hurricane Andrew. Global Environmental Change Part B: Environmental Hazards, 4(2-3), 45-58. https://doi.org/10.1016/S1464-2867(03)00005-6
[44] Chang, S.E., & Rose, A. (2012). Towards a Theory of Economic Recovery from Disasters. International Journal of Mass Emergencies and Disasters, 32(2), 171-181.



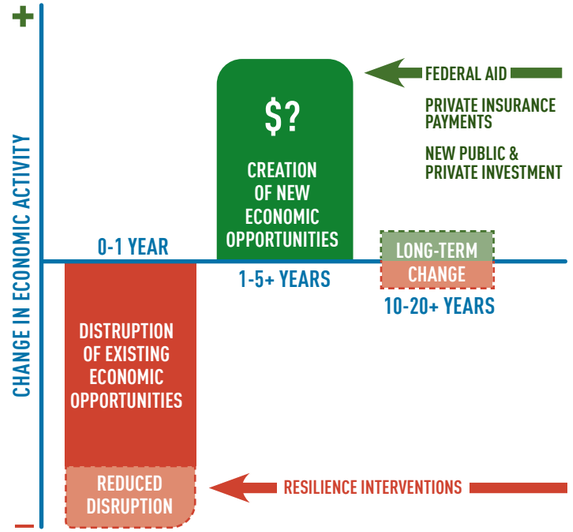


## Dynamic Responses to Business and Economic Disruption

A natural hazard event typically results in an immediate physical effect that produces a shock to the economy. This shock occurs as capital is destroyed and disrupted, immediately impacting the productive potential of the economy. Exhibit 4 shows the initial disruption as a negative change in existing economic opportunities. Interventions that increase resiliency, such as investments in physical infrastructure, can reduce the size of this initial shock.

Once the shock occurs, the economy immediately begins to respond as public and private entities initiate response and recovery efforts. At this stage, many businesses temporarily close because of direct or neighborhood damage, disruptions in utility and transportation services, and the inability of employees to work. As goods and services are no longer being produced and consumed, economic activity drops. The distribution of the effect across sectors is variable. For some sectors, such as construction, this drop may be brief or not occur at all. For other sectors, such as tourism, the effect may be substantial.

**EXHIBIT 4**
**ECONOMIC EFFECTS OF SHOCK AND RESPONSE OVER TIME**





Pyne Gould building destroyed by the 2011 earthquake, Christchurch, NZ. (Source: Wikipedia)

As rebuilding progresses, economic disruption in many sectors will diminish as businesses reopen and begin producing goods and services again. For many businesses within the public sector, financial resources from outside the region will begin to arrive through insurance payments and public emergency aid. These payments represent money that would not have otherwise arrived in the economy and are used to rebuild capital. They directly support industries engaged in the rebuilding efforts, and indirectly support a wide range of other businesses providing inputs to the recovery effort, including satisfying the demands of people — many of whom may come from outside the region — to support the recovery process. The magnitude and timing of this increase in new economic opportunity depend on when federal aid and private insurance payouts arrive.

In the long run, the net effect on the region's economy depends on when and to what extent these economic losses and gains are realized. Research from past disasters suggests that the net effect on economic productivity — measured in terms of aggregate GRP — at the regional level is likely insignificant within a few years of the event.[46] Research also reveals that the distribution of impacts to economic activity across businesses and industry sectors may vary significantly, resulting in clear winners and losers in both the short run and long run.

[45] Rose, A., & Wei, D. (2011). Measuring Economic Risk Benefits of USCG Marine Safety Programs. Washington, DC: United States Department of Homeland Security.
[46] This finding is based on observations and empirical measurements of economic recovery from disasters elsewhere and through time, the majority of which tend to be relatively localized. The CSZ event is likely to significantly affect a broad region of multiple interconnected economies. This study does not explore the cumulative effect of this scale of economic disruption, and there are few historical examples that provide parallel insights.

The CSZ event will disrupt day-to-day activities of local businesses and affect their ability to access labor, capital, and supply chain inputs. While the safety and stability of buildings will cause an initial disruption, a far wider set of inputs affect the resiliency of individual businesses. Extended disruption to public utilities, transportation infrastructure, and regional markets are all external factors that businesses will have to navigate. However, even business-specific characteristics, such as size, financial strength, and the industry sector they work in, may determine their ability to recover.

## Approach to This Analysis

The factors that affect the resiliency of businesses from the CSZ event can be derived from statistical analyses of other sudden-onset natural disasters. Surveys of businesses following Hurricane Andrew and the 1989 Loma Prieta earthquake show commonalities in business response.[47] While each business faced unique challenges, statistical models built on survey data are able to generally predict the probability that firms either temporarily closed or relocated following each event.[48] These resiliency factors are displayed in Exhibit 5. The model does not estimate permanent closure of businesses. Evidence from Christchurch, NZ, following the Canterbury sequence of earthquakes indicates that in the year after the earthquakes, only about 2.5 percent of businesses closed.[49]

In general, businesses that owned their own property were less likely to temporarily close or relocate. Businesses operating in the wholesale and service sectors were more likely to close, while manufacturing firms were more likely to relocate. Following the Loma Prieta earthquake, businesses with greater building damage or loss in utility service were more likely to close. While neither of these events match the severity or type of disruption expected from the CSZ event, they provide a useful structure for modeling business resiliency in the Portland region.

Using the framework described in Section 1, these resiliency factors are applied to individual business characteristics from the QCEW data matched to building-specific damages estimated by the DOGAMI study. To predict temporary business closure following the CSZ event, the functional form of the Loma Prieta closure model is applied to the businesses and expected CSZ structural impacts in the Portland region.[50] Business characteristics that are unknown at the individual level but are known at the aggregate county level (i.e., gender and racial identity of business owners) are randomly assigned to match the broader distribution and resampled 500 times.

**EXHIBIT 5 FACTORS AFFECTING THE PROBABILITY OF BUSINESS CLOSURE OR RELOCATION**

| BUSINESS CHARACTERISTIC | BUSINESS CLOSURE | | BUSINESS RELOCATION | |
|---|---|---|---|---|
| | Loma Prieta | Hurricane Andrew | Loma Prieta | Hurricane Andrew |
| Ownership of Business Property | ↓ | | ↓ | ↓ |
| Wholesale Sector | ↑ | ↑ | | |
| Building Damage | ↑ | | ↑ | ↑ |
| Electricity Disruption | ↑ | | | |
| Phone Disruption | ↑ | | | |
| Service Sector | | ↑ | ↑ | |
| Business Size | | ↓ | | |
| Transportation Problems | | ↑ | | |
| Manufacturing Sector | | | ↑ | |
| Business in URM | | | ↑ | ↑ |
| Building Contents Damage | | | | ↑ |
| Financial Condition of Business | | | | ↑ |
| Sewer/Wastewater Disruption | | | | ↑ |

Source: Wasileski et al. (2011)

↑ INCREASED PROBABILITY ↓ DECREASED PROBABILITY NO MEASURED EFFECT

[47] Wasileski, G., Rodríguez, H., & Diaz, W. Business closure and relocation: a comparative analysis of the Loma Prieta earthquake and Hurricane Andrew. Disasters, 35(1), 102-129. https://doi.org/10.1111/j.1467-7717.2010.01195.

[48] The survey population did not include firms that permanently closed as a result of the disaster, as there was no reliable method to identify and reach these firms. Thus, these estimates do not account for the share of firms that permanently closed and the resulting impacts to employment and wages.

[49] Kachali, H., Whitman, Z. R., Stevenson, J. R., Vargo, J., Seville, E., & Wilson, T. (2015). Industry sector recovery following the Canterbury earthquakes. International Journal of Disaster Risk Reduction, 12, 42-52.

[50] This approach is known as "function transfer" & applies the rate of business effects from previous studies to Portland businesses & the CSZ scenario. Other adjustments are made to account for differences in the time, extent of damage, where possible.





Of particular interest in the Portland region is the effect that unreinforced masonry buildings (URMs) will have on disaster recovery. In the City of Portland alone, there are more than 1,800 URMs that are vulnerable to extensive damage from an earthquake if not seismically retrofitted. These URMs, generally built prior to 1960, are characterized by brick or cinder-block construction and pose safety hazards to those inside the building, as well as those nearby. In major earthquakes, these structures can suffer catastrophic collapse. Even if they remain standing, they can be fundamentally unstable, leading to mandatory restriction of access to streets and buildings nearby.

For example, in the 2010-2011 Christchurch earthquakes, the density of URMs in the central business district necessitated the creation of mandatory cordon zones that excluded access to anyone until all buildings were demolished or stabilized.[51] Following the 2010 earthquake, a cordon zone was established around the central business district (CBD) but was rapidly reduced to limit access to only specific vulnerable buildings. Following aftershocks in December and the February 2011 earthquake, remaining barricades were credited with saving lives, but additional damage necessitated re-establishing the cordon zone throughout the CBD. It remained in place for months, but was gradually reduced as rebuilding addressed vulnerable structures. Half of the area originally cordoned was still inaccessible as of July 2011. By May 2012, 23 blocks were still under cordon. Eventually, upward of 50 percent of the 2,000 buildings in the CBD were damaged beyond repair and were demolished.[52]

To model the effect of URM instability in the Portland Metro region, cordon zones were identified around each URM equal to one and a half times the height of that URM. Any businesses within these cordon zones are expected to suffer the same physical structural impacts as their adjacent URM, even if they themselves are in a stable building.

## Portland Regional Economy

The Portland regional economy is structurally, functionally, and technologically different than the California central coast in 1989, southern Florida in 1992, or Christchurch, NZ, in 2011.

The Portland regional economy is the source of substantial wealth for residents and businesses. As of 2017, it was the 23rd largest metropolitan economy, but only the 25th by population. A diverse combination of tradeable goods manufacturing, advanced technology sectors, and a broad set of goods and services establishments like breweries make up industry clusters that support substantial value-added enterprises in the region. Major industry clusters include clean technology, computer and electronics, health sciences, metals and machining, software and media, and sporting equipment and apparel design. These sectors and businesses are broadly distributed across the metropolitan area.

At the time of this study, there were almost 78,000 businesses across Clackamas, Clark, Columbia, Multnomah, and Washington Counties employing nearly 1.2 million workers.[53] The highest density of URMs is in Multnomah County, and while 2,920 businesses are located in a URM, nearly twice that many (5,233) may be affected by one. A summary of business characteristics is displayed in Exhibit 6.

## Direct Disruption to Businesses

Combining DOGAMI building damage with the business resiliency model produces an estimate of the number of businesses expected to temporarily close following the CSZ event.[54] While the exact timeline of the broader physical recovery from the CSZ event is unknown, the extent of the impacts are broad, with roughly 70 percent of firms likely to be forced to temporarily close, affecting over three-quarters of a million jobs. Assuming that the closure period lasts at least one month, this will result in a loss of over $4.3 billion in income in the region. Impacts are relatively larger in Multnomah County and in the retail sector, while Clackamas County, and the agricultural sector fair marginally better. Absolute impacts on jobs and income are largest in the health care and manufacturing sectors, respectively. County-level and industry sector impacts are summarized in Exhibits 7 and 8. The share of jobs disrupted by square mile is displayed in Exhibit 9.


Masonry buildings in Portland's Old Town Historic District. (Source: Loopnet)

[51] Chang, S. E., Taylor, J. E., Elwood, K. J., Seville, E., Brunsdon, D., & Gartner, M. (2014). Urban Disaster Recovery in Christchurch: The Central Business District Cordon and Other Critical Decisions. Earthquake Spectra. doi: 10.1193/022413EQS050M.

[52] Ibid.

[53] Detailed firm-specific QCEW data were not available for Clark County. Modeling results were applied to publicly available aggregate firm statistics to produce estimates for Clark County.

[54] Applying the business-closure model to firms in the Portland region produces an expected probability of closure for each firm. The aggregate total of these individual probabilities is the expected number of firms that will close.

## EXHIBIT 6 BUSINESS CHARACTERISTICS IN STUDY AREA

| COUNTY | # OF BUSINESSES | # OF EMPLOYEES | AVERAGE PAY | AVERAGE BUSINESS DAMAGE | # OF BUSINESSES IN A URM | # OF BUSINESSES IN A CORDON ZONE |
|---|---|---|---|---|---|---|
| Clackamas | 13,415 | 18,0194 | $49,353 | 0.07 | 233 | 233 |
| Clark | 13,915 | 155,592 | $50,879 | N/A | N/A | N/A |
| Columbia | 1,157 | 11,022 | $38,737 | 16.00% | 30 | 58 |
| Multnomah | 31,760 | 509,737 | $56,918 | 14.00% | 2,507 | 4,792 |
| Washington | 17,718 | 291,895 | $67,495 | 10.00% | 150 | 150 |
| TOTAL/MEAN | 77,965 | 1,148,440 | $52,676 | 12.00% | 2,920 | 5,233 |

Note: Disaggregate QCEW data was not available for Clark County. Source: QCEW, DOGAMI

## EXHIBIT 7 DIRECT BUSINESS DISRUPTION ESTIMATES, BY COUNTY

| COUNTY | # OF BUSINESSES DISRUPTED | % OF BUSINESSES DISRUPTED | # OF JOBS AFFECTED | LOST INCOME (MILLIONS $) |
|---|---|---|---|---|
| Clackamas | 9,180 | 68% | 133,757 | $553 |
| Clark | 9,807 | 70% | 109,006 | $457 |
| Columbia | 809 | 70% | 7,766 | $24 |
| Multnomah | 22,867 | 72% | 397,858 | $1,920 |
| Washington | 12,310 | 70% | 222,982 | $1,330 |
| TOTAL/MEAN | 54,973 | 70% | 871,369 | $4,284 |

Note: "Disrupted" refers to a temporary closure of a firm. The estimate of lost income assumes an average one-month closure period. Source: ECONorthwest analysis of QCEW, DOGAMI, and City of Portland data.

## EXHIBIT 8 DIRECT BUSINESS DISRUPTION ESTIMATES, BY INDUSTRY SECTOR

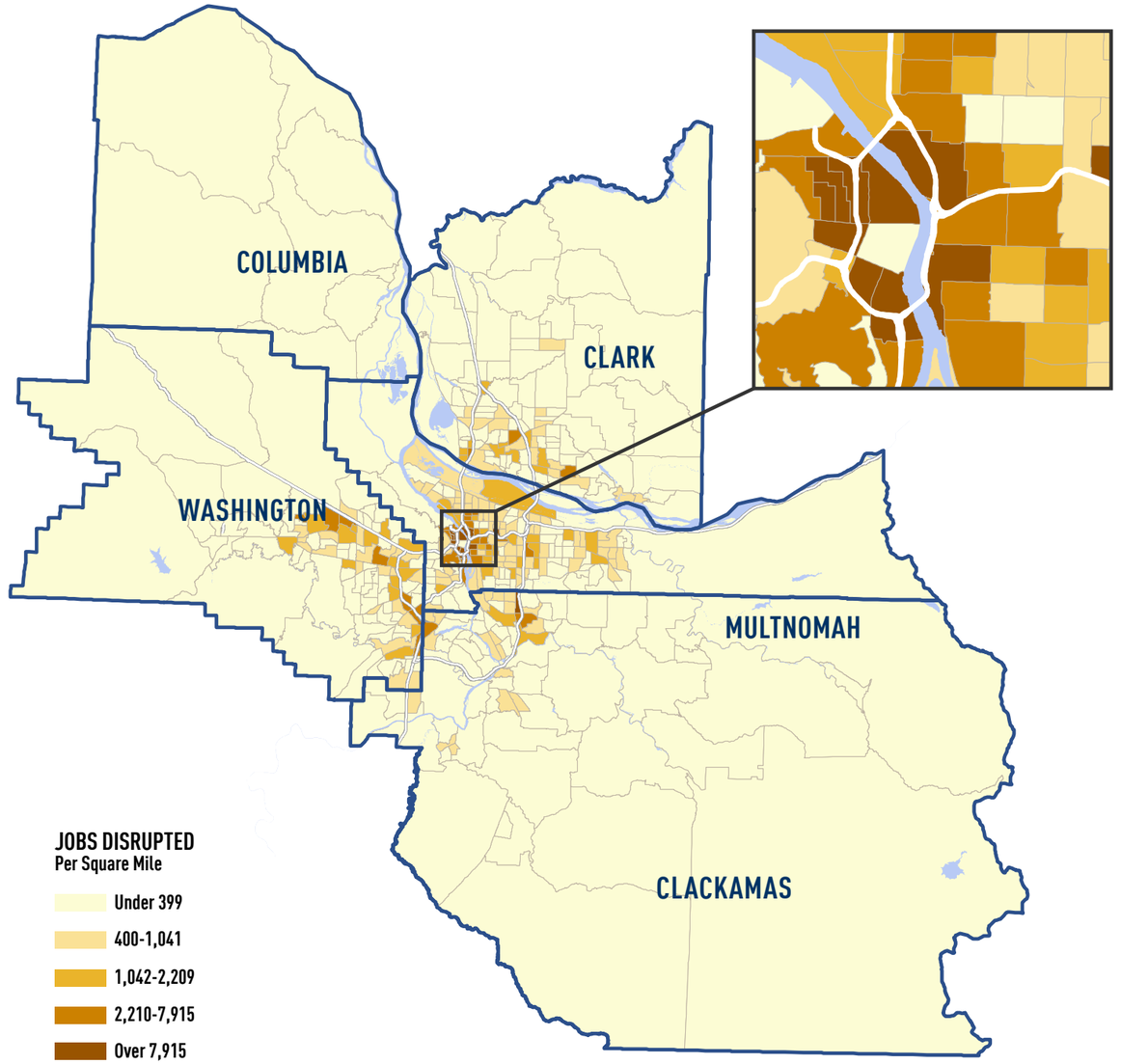
| INDUSTRY SECTOR | # OF BUSINESSES DISRUPTED | % OF BUSINESSES DISRUPTED | # OF JOBS AFFECTED | LOST INCOME (MILLIONS $) |
|---|---|---|---|---|
| Manufacturing | 2,298 | 70% | 92,332 | $654 |
| Health Care and Social Assistance | 7,148 | 71% | 112,800 | $533 |
| Professional, Scientific, & Technical Services | 6,868 | 71% | 55,454 | $391 |
| Management of Companies and Enterprises | 431 | 65% | 32,111 | $364 |
| Educational Services | 1,341 | 72% | 68,218 | $304 |
| Retail Trade | 5,168 | 77% | 106,371 | $285 |
| Wholesale Trade | 4,150 | 75% | 43,890 | $264 |
| Construction | 4,551 | 67% | 45,947 | $246 |
| Finance and Insurance | 2,106 | 61% | 29,639 | $214 |
| Public Administration | 299 | 66% | 37,363 | $205 |
| Administrative and Remediation Services | 2,800 | 70% | 49,885 | $166 |
| Accommodation and Food Services | 4,459 | 73% | 75,216 | $137 |
| Information | 1,384 | 71% | 19,583 | $136 |
| Transportation and Warehousing | 1,068 | 62% | 29,896 | $129 |
| Other Services | 7,032 | 70% | 33,228 | $106 |
| Real Estate and Rental and Leasing | 2,405 | 71% | 14,205 | $59 |
| Arts, Entertainment, and Recreation | 792 | 73% | 15,326 | $42 |
| Utilities | 68 | 62% | 3,171 | $27 |
| Agriculture, Forestry, Fishing and Hunting | 474 | 59% | 6,495 | $20 |
| Other | 133 | 58% | 237 | $1 |

Note: "Disrupted" refers to a temporary closure of a firm. The estimate of lost income assumes an average one-month closure period. Source: ECONorthwest analysis of QCEW, DOGAMI, and City of Portland data.





## EXHIBIT 9 JOBS DISRUPTED BY SQUARE MILE




Source: ECONorthwest
Note: Individual county maps available in county summaries, provided in the Technical Appendix.

## Effects of Policy Interventions to Reduce Business Disruption

Regional leaders have an opportunity to make investments or advance policy changes that can reduce the expected disruption to businesses from the CSZ event. These are actionable changes that can be made now that have an impact on economic recovery following an earthquake. Through discussions with the stakeholder advisory group, four specific policy interventions were developed for study, specifically:

1. Reinforcing transportation networks;
2. Reducing disruptions to utility services;
3. Retrofitting URMs; and
4. Retaining population.

These four scenarios are modeled to measure the relative benefits of their policy outcomes; however, this study does not evaluate the mechanism by which those outcomes are delivered. For instance, reinforced transportation networks can help enable businesses to continue accessing important markets, and modeling can estimate the degree to which they reduce business disruption. However an expansive engineering analysis would be necessary to identify roads and bridges at risk and propose specific retrofits to improve their survivability after a severe earthquake. The cost of these retrofits could then be compared with the expected benefits. While the decision to pursue a public policy action should, in part, consider the relative benefits and costs, this study does not make recommendations for policies or their implementation. Rather, this study evaluates the relative magnitude and distributional impact of these four policy scenarios. The specific mechanisms by which these four policy interventions are modeled are described in the sections below.

### Reinforcing Transportation Networks

Many of the roads and bridges in the region were designed and constructed prior to the implementation of seismic engineering standards. These critical transportation assets can be damaged or experience catastrophic failure during a major earthquake. During the Loma Prieta earthquake, a portion of the San Francisco-Oakland Bay Bridge, built in 1936, collapsed and remained closed for over a month. The double-decker Cypress Freeway, built in the 1950s, took nine years to rebuild, at a cost of $1.2 billion.[56]

The Portland region has grown around both the Willamette and Columbia Rivers, and many individuals and businesses count on the ability to cross these major waterbodies, as displayed in Exhibit 10. However, of the 12 bridges in Portland that cross the Willamette River, seven were built before 1936. The loss of this major transportation infrastructure would not only inhibit economic activity in the region, but the recovery may take many months or years due to the complexity involved with rebuilding bridges. The ability to retain functional river crossings over the Willamette and Columbia rivers may dramatically improve regional economic resiliency.

Currently, there are efforts being undertaken to evaluate the seismic resiliency of these structures, and in some cases, implement retrofits that will reduce damage and improve the ability to repair them following an earthquake. Multnomah County is leading the "Earthquake Ready Burnside Bridge" project, which is evaluating either a seismic retrofit or complete reconstruction of this critical transportation infrastructure.[56] The Oregon Department of Transportation conducted an analysis of investment opportunities to enhance seismic resilience of state lifeline routes in partnership with counties throughout the region in 2019-2020. Building on the work of DOGAMI and ODOT, the RDPO and Metro are leading a seismic update to designations of the Regional Emergency Transportation Routes (RETRs) in 2020. Completion of this effort and others will enhance economic resiliency in the region.

In the model used to predict business disruption following the CSZ event, transportation problems are rated on an ordinal scale between 0 and 3. Following the Loma Prieta earthquake, 27 percent of firms experienced some transportation problems, with less than 4 percent of firms experiencing major disruption. This variable had a marginally positive effect on the probability that a firm would close. A precise estimate of the overall transportation infrastructure impacts from the CSZ event was not available, so this initial distribution is maintained for firms in the Portland Region. To better account for commuting patterns and remote work capabilities in the region, this distribution is adjusted to match the share of employees that cross a river for work by county, and the share of employees that are not able to work remotely by industry.[51]

To model the potential effects of policies that reinforce transportation networks, these values are reduced to 0 for all firms. This creates a scenario in which transportation is not a source of business disruption following an earthquake.

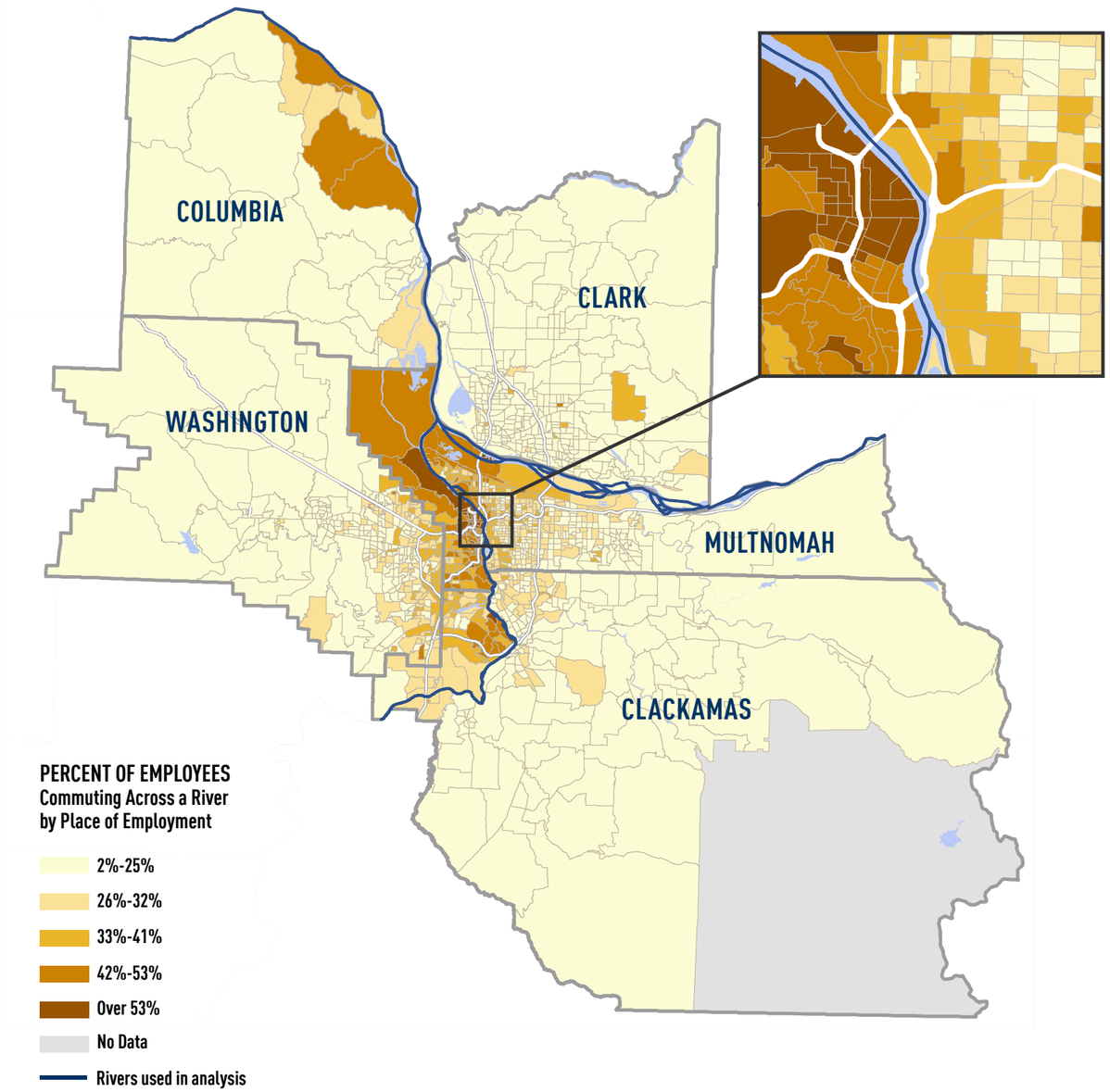
This policy is expected to prevent approximately 240 firm closures and retain about 3,000 jobs. Assuming a 1 month

[55] U.S. Department of Transportation, Federal Highway Administration. (1998). "Replacing Oakland's Cypress Freeway." *Public Roads* 61(5). March/April.
[56] Multnomah County, Department of Community Services. (2020) "Earthquake Ready Burnside Bridge." Accessed at https://multco.us/earthquake-ready-burnside-bridge
[57] As businesses have responded to COVID-19, a primary strategy during stay-at-home orders has been to shift to remote work arrangements. This rapid adjustment is likely to lead to long-term shifts in the capacity of some industries to effectively maintain business continuity with most workers operating remotely. However, this capacity is dependent on the availability of reliable communications infrastructure, which may not be available following a CSZ event.





**EXHIBIT 10** SHARE OF WORKERS COMMUTING ACROSS A RIVER




Note: If state lines are crossed, it's assumed that a river will also be crossed. Employees who live outside of the study area are not included in this analysis.
Source: ECONorthwest analysis of U.S. Census Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES), 2017 data. Available at https://lehd.ces.census.gov/data/.

closure period, this would retain approximately $16.75 million in regional income. Impacts are fairly consistent across counties. These benefits would be larger if the initial impacts to transportation were greater than those assumed in the baseline scenario. They may be smaller if a greater share of the workforce has been able to accommodate remote work opportunities.

### Reducing Disruption to Utility Services

Power, telecommunications, water, and sewer services are critical for the safety and continued operation of businesses. Both above- and below-ground power and telecommunication lines can be severed during an earthquake. Underground water and sewer lines can suffer substantial failure, leading to loss of water, boil orders, and unsanitary conditions throughout the region. Generally, following major hurricanes, nationwide utility repair assets are redirected to impacted regions to reconnect homes, businesses, and neighborhoods to these lifeline services. In the wake of a major earthquake with expected impacts across the entire Pacific Northwest, access to repair crews may be limited and recovery may take substantially longer.

Actions that can be taken now to reduce disruption to utility services following the CSZ event can include seismic upgrades, constructing redundancy in distribution systems, or staging repair equipment and backup water supplies.

The earthquake business response model includes ordinal rankings representing electricity, phone, water, and sewage disruption. Telecommunication infrastructure was dramatically different at the time of the 1989 Loma Prieta earthquake. Businesses and households relied heavily on landline telephones, and current wireless telecommunication infrastructure did not exist. However, the "phone" variable in the model can also serve as a proxy for today's high-speed fiber-optic telecommunication infrastructure, on which many wireless networks rely.

A series of extensive conversations were held with utility managers in the region to determine the expected disruption to utility services following the CSZ event. Due to some of the broad uncertainties of the specific nature of physical and structural disruption, a more precise estimate was not available. Thus, the baseline scenario is based upon business-level impacts following the Loma Prieta earthquake. In that event, 90 percent and 75 percent of firms experienced some disruption of power and phone service, while 60 percent and 90 percent did not lose water or sewer service respectively. CSZ structural impacts are likely to exceed these values.

In modeling this scenario, it is assumed that no firms in the Portland Metro region will experience any loss of utility services following the CSZ event. While this level of resilience is substantial and possibly unattainable, the results elucidate the importance that utility infrastructure has on economic activity. Should this policy outcome be achieved, it would enable almost 14,000 firms to continue operating employing more than 180,000 jobs. Assuming a one-month closure period, this would protect and save over $800 million in income. Clackamas County businesses would benefit slightly more, and Multnomah County relatively less, but not by large margins. A breakout by County is displayed in Exhibit 12.

### Reinforcing Unreinforced Masonry Structures (URMs)

The prevalence of brick and masonry buildings architecturally defines downtown Portland and the surrounding areas. While their style and age serve as a cultural backdrop to the region, most were built prior to current seismic engineering standards. As described earlier, these buildings also pose a risk to surrounding areas. A building collapse can cause substantial harm to other buildings around it, even if the other buildings are built to modern standards. If a URM does not collapse, it can be unstable following the earthquake and may lead to the designation of cordon zones to protect surrounding areas while it is either demolished or stabilized.

## EXHIBIT 11 REDUCTION IN BUSINESS DISRUPTION FROM REINFORCING TRANSPORTATION NETWORKS, BY COUNTY

| COUNTY | REDUCTION IN BUSINESSES DISRUPTED | % OF BUSINESSES | # OF JOBS AFFECTED | CHANGE IN INCOME (MILLIONS $) |
|---|---|---|---|---|
| Clackamas | 43 | 0.32% | 501 | $2 |
| Clark | 43 | 0.31% | 482 | $2 |
| Columbia | 4 | 0.32% | 30 | $0.1 |
| Multnomah | 94 | 0.30% | 1,242 | $10 |
| Washington | 56 | 0.32% | 781 | $2.6 |
| TOTAL/MEAN | 240 | 0.31% | 3,036 | $16.75 |

Note: "Disrupted" refers to a temporary closure of a firm. The estimate of lost income assumes an average one-month closure period. Source: ECONorthwest analysis of QCEW, DOGAMI, and City of Portland data.





URM buildings can be retrofitted in ways that stabilize the structure and increase the safety of those in and around the building. While these retrofits may not always be able to bring a building up to the highest seismic standard, they represent a substantial increase in safety.

A URM retrofit policy is operationalized in the business response model by adjusting some of the original assumptions about how URMs and their respective cordon zones[58] affect business resiliency. The model has two variables that represent the impact of URMs. One is a URM indicator variable, which is assigned to all businesses in a URM or in a cordon zone. The other is the probability of building damage, produced by the DOGAMI study. All businesses in a URM or in a cordon zone are assigned the URM probability of building damage, regardless of whether they are in a URM. Both of these variables are modified to reflect the outcomes of a URM retrofit policy. All businesses are reassigned a new value for the URM indicator variable (as if they were not in a URM), and the probability of building damage is reverted to each building's original value, thus removing the effect of the cordon zones.

This policy is expected to prevent approximately 530 firm closures and retain about 7,600 jobs. Assuming a one-month closure period, this would increase regional income by over $40 million. Benefits predominantly accrue to businesses in Multnomah county, since this is where most URMs are located. Exhibit 13 lists the reductions in business disruption by County.

> The City of Portland adopted a URM policy in 2018 that included placarding of URM buildings in the City. However, in 2019 the City removed the placarding requirement after it lost a preliminary legal action brought by URM owners. The City subsequently removed the URM inventory from its website, in response to concerns that the listing had a blighting effect on the property. URM retrofits are costly, and a mandatory retrofit requirement would have a disparate impact on communities already harmed by other racist City policies. At the same time, URM structures serve many tenants and workers of color who would be harmed in an earthquake. Future policy discussions will need to center the well-being of communities of color, which are at greatest risk of displacement — from either an earthquake or economic hardship."

## EXHIBIT 12 REDUCTION IN BUSINESS DISRUPTION FROM REDUCING DISRUPTION TO UTILITY SERVICES, BY COUNTY

| COUNTY | REDUCTION IN BUSINESS DISRUPTION | % OF BUSINESSES | # OF JOBS AFFECTED | CHANGE IN INCOME (MILLIONS $) |
|---|---|---|---|---|
| Clackamas | 2,485 | 18.50% | 30,796 | $125 |
| Clark | 2,491 | 17.90% | 27,851 | $118 |
| Columbia | 209 | 18.10% | 1,937 | $6 |
| Multnomah | 5,553 | 17.50% | 75,989 | $350 |
| Washington | 3,237 | 18.30% | 44,805 | $210 |
| TOTAL/MEAN | 13,975 | 18.06% | 181,378 | $809 |

Note: "Disrupted" refers to a temporary closure of a firm. The estimate of lost income assumes an average one-month closure period. Estimates for Clark County are not available due to limited QCEW data availability.
Source: ECONorthwest analysis of QCEW, DOGAMI, and City of Portland data.

## EXHIBIT 13 REDUCTION IN BUSINESS DISRUPTION FROM REINFORCING URMS, BY COUNTY

| COUNTY | REDUCTION IN BUSINESS DISRUPTION | % OF BUSINESSES | # OF JOBS AFFECTED | CHANGE IN INCOME (MILLIONS $) |
|---|---|---|---|---|
| Clackamas | 25 | 0.2% | 372 | $1 |
| Columbia | 7 | 0.6% | 82 | $0.2 |
| Multnomah | 486 | 1.5% | 6,979 | $40 |
| Washington | 16 | 0.2% | 246 | $0.6 |
| TOTAL/MEAN | 534 | 0.8% | 7,679 | $41.8 |

Note: "Disrupted" refers to a temporary closure of a firm. The estimate of lost income assumes an average one-month closure period. Estimates for Clark County are not available due to limited QCEW data availability.
Source: ECONorthwest analysis of QCEW, DOGAMI, and City of Portland data.

[58] The radius of a cordon zone is defined as 1.5 times the height of the respective URM building.

### Retaining Population

Research from 10,000 disaster events that have occurred in the United States between 1920 and 2010 suggests that one of the lasting economic effects of natural disasters is net population loss. For severe disasters, case studies have shown large effects on population — up to a 12 percent loss. These losses followed hurricanes, floods, and droughts in different parts of the United States.[59] Looking across a larger number of severe disasters, researchers found the effect more moderate — about a 1.5 percent decrease in population from a county. A survey of Portland-area residents found that, in the case of a disaster that left their household without running water or electricity for two weeks, 41 percent "strongly agreed" or "somewhat agreed" that they would leave Portland.[60] It was not explicit whether they would leave permanently or temporarily, but it's likely at least some would not return.

Population loss has several effects on a region's economic health. As people leave an area, they take with them their knowledge and skills (human capital), and the money they would have spent for goods and services. Both of these losses have the potential to reduce the economic productivity of a region. As people leave, housing prices decline. The same study of county-level disaster effects found that housing prices and rents decreased by 5.2 percent and 2.5 percent, respectively.

Population losses may have disproportionate effects on a region's economic health if a higher proportion of its wealthiest people choose to leave. There is evidence that the probability

2013 tornado in Moore, Oklahoma (Source: Official White House, Photo by Pete Souza)

The threat of Hurricane Bret, being rated at a force four, led residents to leave Padre Island and Corpus Christi, 1991. (Source: Wikipedia)

of out-migration is not the same for all income brackets. On average, local poverty rates increase by about 0.8 percent after a severe disaster, which suggests that the population remaining after a severe disaster is less wealthy. This effect likely occurs because people with more financial resources are more likely to be able to relocate following a disaster. This perpetuates the decline in wealth and economic productivity in an area.

Resilience interventions that focus on population retention could have a positive economic effect over the long run. These interventions may take the form of reducing overall physical disruption so household and business disruptions are of a shorter duration and are less impactful for more people.

**Resilience interventions could also take the form of enhancing social capital within neighborhoods so more residents feel connected to and invested in mitigation and recovery efforts, and creating opportunities for local and small businesses to productively engage in recovery efforts.**

This strategy was specifically identified by business representatives during the key-informant interview process as an important consideration in whether they would reopen or relocate outside of the area.

Quantitative estimation of this residency intervention was not possible through adjustments to the resiliency factor model. However, the regional economic model could test the Portland region economy's sensitivity to retaining population. The results of that analysis are discussed in Section 5.

[59] Boustan et al. 2017

[60] DHM Research. (2017). *Portland Bureau of Emergency Management Preparedness Report*. June. Retrieved from https://www.portlandoregon.gov/pbem/article/643129





The CSZ event will cause disproportionate impacts on people throughout the Portland region. Just as businesses have varying capacity to respond to a major natural disaster, people have varying capacity to respond and recover. For example, the same shock can have more severe or longer-lasting consequences for people with limited financial resources or who face social barriers in society. This section explores the geographic variability of social vulnerability and its intersection with potential damage and business disruption in the Portland region. The economic effects of the earthquake will depend on both the infrastructure that is damaged as well as the preparedness and responses of the people impacted.

## Measuring Social Vulnerability

Capturing all the social and economic contributors that lead to increased vulnerability in the population is complex. Many measures of structural vulnerability can be hard to quantify because data may not be available at scales fine enough for meaningful policy interventions, the measure is antiquated, or sub-populations may be geographically dispersed. Despite these limitations, even an aggregate estimate of vulnerability within a region's population can help identify potential areas of concern, lead to more equitable response and recovery efforts, and improve the trajectory of economic recovery for the region.

This study uses the Social Vulnerability Index (SVI) to identify and measure vulnerable populations in the Portland region. The SVI, developed by the CDC, accounts for four main characteristics that may lead to increased vulnerability:

- Socioeconomic Status
- Household Composition and Disability
- Minority Status and Language
- Housing and Transportation

The SVI is composed of 15 individual variables in these four categories. To construct the SVI for the Portland region, data for these variables was constructed for each census tract (consistent with the unit at which building damage and business impacts are reported in Section 3).[61] Data for each tract was then assigned a percentile rank relative to all other census tracts in the Portland region.[62] The vulnerability index is reported as a range between 0 and 1 to compare tracts. Lower values correspond with lower vulnerability, while higher values correspond with higher concentrations of vulnerability.

The map in the top left of Exhibit 14 shows the SVI scores by census tract, with darker shaded areas having a higher SVI, meaning a higher proportion of people in the tract have socioeconomic and demographic characteristics consistent with variables in the SVI.[63] This map indicates that Clark, Multnomah, and Washington counties have higher concentrations of social vulnerability, while Columbia and Clackamas counties have lower levels of social vulnerability overall, with higher vulnerability in a few areas.

Not all people in areas of high social vulnerability are of higher risk, and vice versa, and the labeling of areas does not necessarily represent actual lived experiences, preparation measures, or ability to respond to a CSZ event. Planners and policy makers should use this to further engage community members and work toward more equitable outcomes.

## Social Vulnerability and Earthquake Damage

To produce estimates by census tract of building damage that are most relevant to social vulnerability, the DOGAMI data are filtered to residential structures. These residential building damage estimates are averaged across census tracts. Building damage levels are shown in the small map in the upper right of Exhibit 14.

The large map in Exhibit 14 shows the relationship between social vulnerability and building damage arising from a CSZ event. Census tracts with high levels of vulnerability and high levels of residential building damage are dark purple. Tracts with high levels of vulnerability but low levels of damage are more blue, while tracts with high levels of damage but lower levels of vulnerability are more orange. Comparisons of building damage and social vulnerability indicate that people of all social vulnerability measures are expected to experience structural damage following the CSZ event. However, concentrations of darker purple, where the CSZ event may produce the highest impacts among vulnerable populations, occur in Clark, Multnomah, and Washington counties.

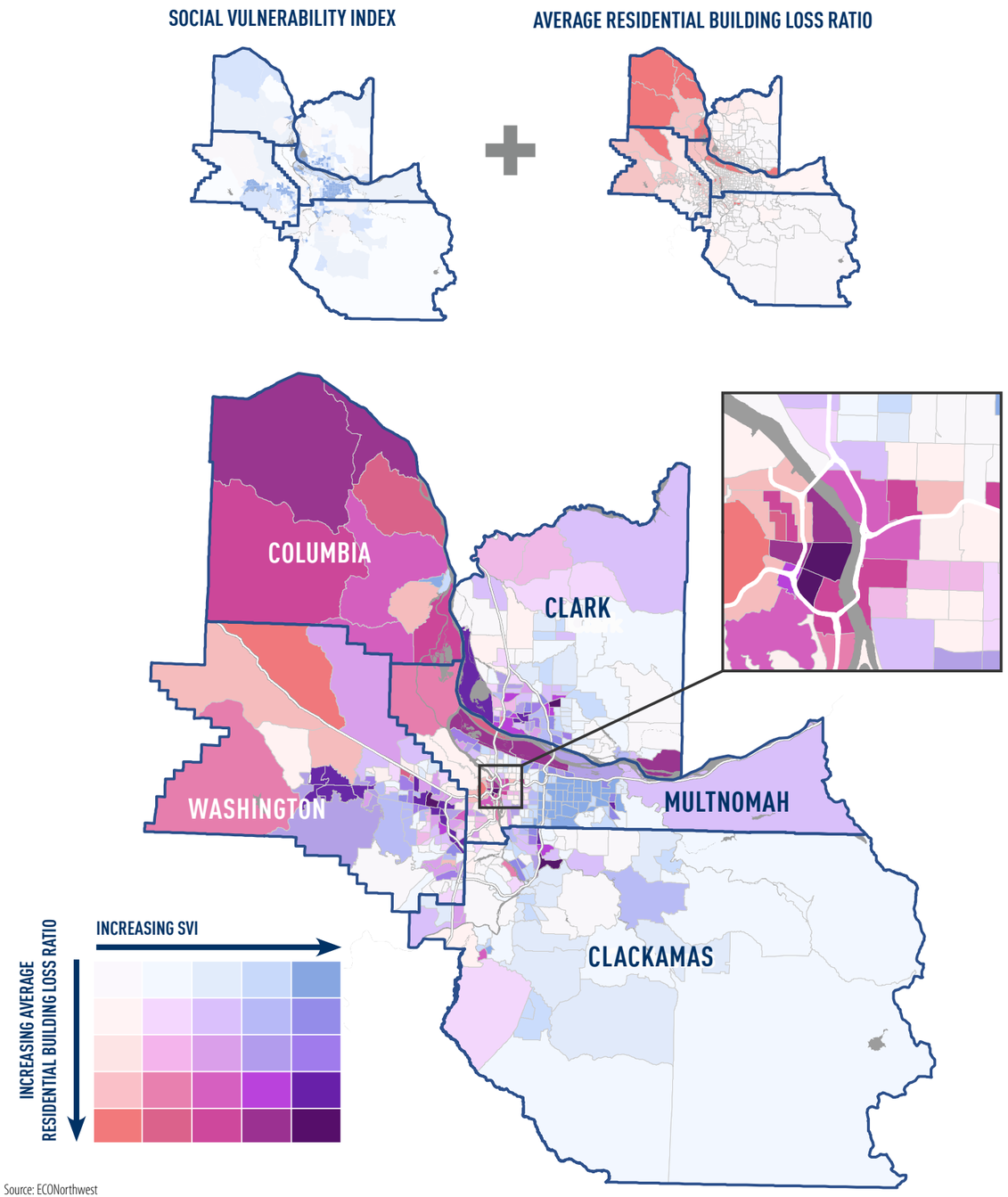
This analysis suggests that there are variations in risk of damage due to a CSZ event by socioeconomic and demographic status across the Portland region. Areas with higher social vulnerability and higher levels of building damage likely will recover more slowly, and the physical impacts may manifest in populations in different ways or to a greater degree than similar impacts in areas with lower social vulnerability. Tracts with a higher SVI and lower levels of damage are also important, as even if these populations are not dealing with damage to their own residences, they likely still have a lower capacity to respond and adapt to damaged infrastructure (e.g., transportation and communication systems), disrupted employment, and disruptions in social capital.

[61] The methodology and data used to construct this SVI, including a description of the 15 component variables, are described in more detail in the Technical Appendix.

[62] The SVI typically compares a particular local geography (e.g., a county) to a state or the nation. This analysis constructs the SVI within the Portland region, comparing census tracts within the region to each other. A tract assigned a score of 1 has the highest level of vulnerability across the 15 variables compared with all other tracts in the Portland region, while a tract assigned as score of 0 has the lowest level of vulnerability.

[63] Larger versions of the two smaller maps are included in the Technical Appendix.

## EXHIBIT 14 SOCIAL VULNERABILITY AND EARTHQUAKE DAMAGE




Source: ECONorthwest

### Social Vulnerability and Business Disruption

People affected by the CSZ event are also workers and business owners. People with higher social vulnerability may have a harder time returning to work, and they would likely be disproportionately impacted by business disruption. Exploring the intersection between vulnerable populations and the characteristics of disruption to businesses reveals areas where patterns of business disruption may disproportionately affect vulnerable populations. For example, some types of employment will be able to resume sooner than others, such as construction jobs that will be needed to rebuild.

To measure the risk of employment disruption to vulnerable populations, the results of the business disruption analysis are compared with demographic data to understand how social vulnerability might exacerbate disruption or displacement in the labor market.

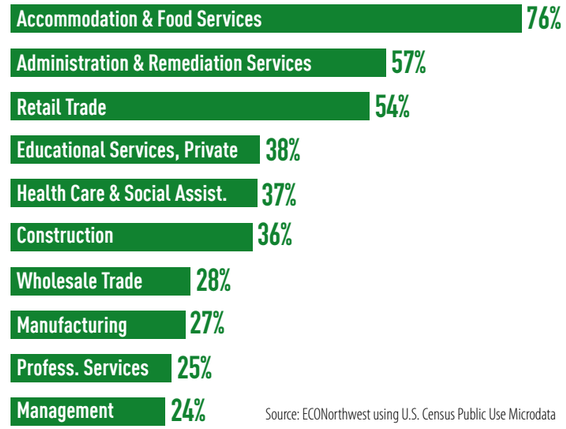
Exhibit 15 shows the share of low-income[64] workers by the 10 industries most likely to be disrupted by the CSZ event. Low-income workers in the tourism and hospitality sector, along with retail and wholesale trades, are anticipated to be at a higher risk of job loss. The industries with the highest proportion of low-income workers are: accommodation and food services (76%), administrative and remediation services (57%), and retail trade (54%). These industries are highly dependent on discretionary spending, which is likely to decline and shift toward essential household consumer goods after the CSZ event. Tourism spending will likely decline immediately after the CSZ event while the region rebuilds its infrastructure.

Rapid changes in consumer spending are not the only risk for many low-income and minority workers in these vulnerable industries. The option to work remotely is less likely to be an option for these employees who may need to be on-site to perform the requirements of their job. Employees in these industries have fewer opportunities to accomplish their work from an alternate location (see Exhibit 16). For many of these workers who may already have limited access to resources, the loss of income is likely to compound their ability to recover after a major disruptive event.

Employees are not the only segment of the population that is likely to experience disproportionate effects of the CSZ event. The owners of businesses where many of these vulnerable individuals work may also face greater risk of displacement. Businesses owned by persons of color or located in low-income areas may experience limited access to capital, less technical assistance after a major disruptive event, or less benefit from policy solutions aimed at offsetting business losses.[65]

In the Portland region, slightly over 15 percent of businesses are owned by people of color. Many of those businesses are concentrated in at-risk industries in the tourism and hospitality industry, or in other services, including many types of small businesses, from grant-making to laundry services, which may have less diverse supply chains and rely on consumer willingness to spend on discretionary services.

## EXHIBIT 15 SHARE OF LOW-INCOME WORKERS IN INDUSTRIES AFFECTED BY CSZ, PORTLAND METRO




Source: ECONorthwest using U.S. Census Public Use Microdata

## EXHIBIT 16 SHARE OF WORKERS WHO CAN WORK REMOTELY, 2017-2018

| INDUSTRY | SHARE OF WORKERS |
|---|---|
| Professional Services | 47.4% |
| Financial Services | 46.7% |
| Information | 45.1% |
| Manufacturing | 25.7% |
| Education and Health Services | 23.7% |
| Other Services | 22.6% |
| Public Administration | 21.8% |
| Construction | 14.4% |
| Wholesale and Retail Trade | 13.9% |
| Transportation and Utilities | 12.5% |
| Forestry, Fishing, and Hunting | 10.4% |
| Leisure and Hospitality | 6.8% |
| Mining | 0% |

Source: Bureau of Labor Statistics, National Estimates.

[64] For this analysis, "low income" is defined as 80 percent of Median Family Income for the 5-county region
[65] Wasileski, G., H. Rodruguez, & W. Diaz (2011). Business closure and relocation: a comparative analysis of the Loma Prieta earthquake and Hurricane Andrew. Disasters. 2011, 35(1): 102-129.

Ensuring that resources for existing businesses and potential entrepreneurs are shared across the business community is important to building a resilient economy. During the Great Recession, for example, persons of color experienced disproportionately higher rates of unemployment. However, the ability to transition from employee to business owner was critical to avoiding long periods of unemployment. Many small businesses owned by persons of color helped lead the economic recovery after the recession.[66]

**Opportunities for entrepreneurship would likely be an important component to create new employment opportunities after a major natural disaster such as the CSZ event as well.**

Researchers have documented the importance of entrepreneurs in a post-disaster economy.[67] Ensuring that these opportunities are shared across vulnerable populations experiencing disproportionate impacts will help solidify broader community and economic resilience in the region.

## Social Vulnerability and Economic Disruption

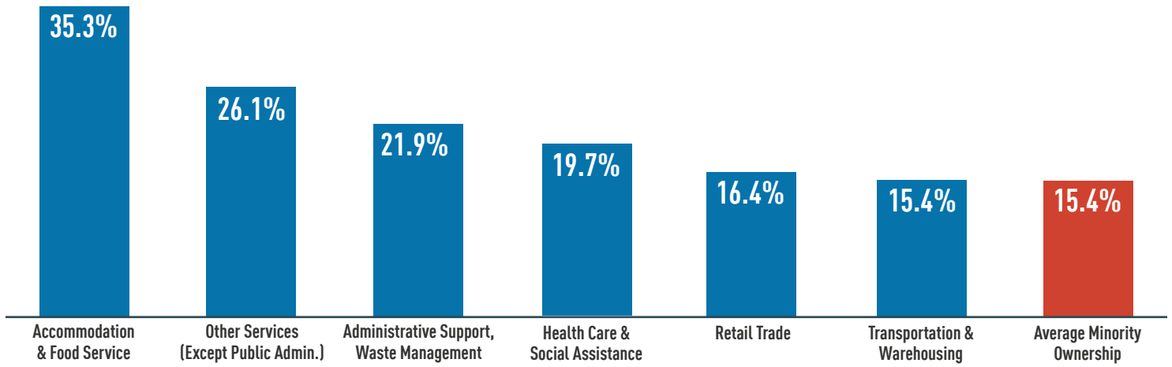
Even if a disaster has a small total economic impact in a region, the impacts on some individuals are likely to be devastating. Examples from past disasters suggest that more vulnerable populations could experience more severe direct impacts from disasters and face barriers to recovery. Evidence from Hurricane Katrina suggests that low-income, elderly, and disabled residents might lack access to transportation needed to evacuate,[68] and thus be more vulnerable in their response to disasters. After the disaster, low-income populations and persons of color[69] could take longer to rebuild due to higher levels of damage, limited personal resources, or challenges navigating bureaucratic processes to access aid.[70]

*"At all phases, up to and including reconstruction, disasters don't simply flatten landscapes, washing them smooth. Rather, they deepen and erode the ruts of social difference they encounter."* [71]

Evidence from Hurricane Andrew documented more damage and slower recovery for neighborhoods with higher portions of people of color, low-income residents, rental housing, and multifamily housing.[72] Because there are inequities in the extent of damage and ability to recover, vulnerable populations can also experience severe and long-lasting post-traumatic stress, depression, and physical health problems following a disaster.[73]

This analysis focused on how natural disasters intersect with economies and therefore cannot capture all aspects of social vulnerability related to such a disruptive event. Public health, sociology, and other disciplines all have important contributions to make to this topic. A broader set of analyses can help policy makers understand the true risks to vulnerable populations from the CSZ event.

**EXHIBIT 17 SHARE OF BUSINESSES OWNED BY PERSONS OF COLOR IN THE PORTLAND METRO REGION, 2012**




Source: U.S. Census, Survey of Business Owners

[66] Lieu, Sifan & J. Parilla. (2020) Businesses owned by women and minorities have grown. Will COVID-19 undo that? Brookings.
[67] Chamlee-Wright & V. Storr. (2008). The Entrepreneur's Role in Post-Disaster Community Recovery: Implications for Post-Disaster Recovery Policy.
[68] Masozera, M., Bailey, M., & Kerchner, C. (2007). Distribution of impacts of natural disasters across income groups: A case study of New Orleans. *Ecological Economics*, 63(2-3), 299-306.
[69] The modern term "persons of color" is used here in place of the term "minority" common in existing literature and U.S. Census data.
[70] Fothergill, A., & Peek, L. A. (2004). Poverty and disasters in the United States: A review of recent sociological findings. Natural hazards, 32(1), 89-110.
[71] Smith, N. 2006. "There's no such thing as a natural disaster." *Items*. Social Science Research Council. June 11. Retrieved May 21, 2020, from https://items.ssrc.org/understanding-katrina/theres-no-such-thing-as-a-natural-disaster/
[72] Zhang, Y., & Peacock, W. G. (2009). Planning for housing recovery? Lessons learned from Hurricane Andrew. Journal of the American Planning Association, 76(1), 5-24.
[73] Substance Abuse and Mental Health Services Admin. (2017). *Disaster Technical Assistance Center Supplemental Research Bulletin: Greater Impact: How disasters affect people of low socioeconomic status.* U.S. Dept. of Health & Human Services.





As businesses and households respond to the CSZ event, their direct impacts will extend far beyond the initial shock to the economy. Any reductions in demand will have indirect impacts throughout the supply chain and will extend further to induced impacts due to reductions in regional income and spending. These broader economic effects associated with the CSZ event are best explored with economic impact models, such as REMI, to measure the change in economic activity in a study region related to external events that result in a discernible change in demand. Typically, these models trace the flow of regional spending across industries to measure changes in jobs, labor income, and gross regional product.

## Approach to This Analysis

Although direct business disruption and response to policy scenarios were evaluated in Section 3, they do not provide sufficient information to use an input-output model to quantify the total economic effect of the CSZ event. Tracing the ripple effects of individual business disruptions through the economy of the Portland metro region is a challenging task, for several reasons:

- Input-output models are not well-suited for simulating the many dimensions of change that occur simultaneously and over time following disruptions like the CSZ event, which would likely result in a disruption to utilities and other lifeline services of unknown extent and duration. This makes the precise timeline for business recovery difficult to predict.
- The CSZ event is in many ways unprecedented in its severity and impact to a major metropolitan region. Evidence from past earthquakes in Japan, Chile, and Christchurch, NZ, are informative, but not necessarily predictive of the level of physical and economic disruption that would occur in the Portland Metro region. Thus, supportive information about the specific extent and duration of physical recovery – which is critical to accurately modeling economic recovery – is limited.
- The initial economic disruption will be met with infusions of new spending from outside the region through federal disaster assistance and, eventually, private insurance payments. The timing and magnitude of these interventions will have a tremendous impact on the long-term path of economic recovery.

A detailed economic impact analysis would require information on the precise extent of damage, duration to recovery, and the amount of new spending (through federal aid and insurance payments). Any assumptions on these factors can potentially outweigh and dampen the effects of the policy interventions evaluated in Section 3. Thus, instead of making qualified assumptions, this analysis uses REMI to quantify the changes in total employment, labor income, and gross regional product resulting from the resilience interventions presented in Section 3. It is important to note that the underlying rationale for using an input-output model for this analysis is not to predict the loss in GRP after the CSZ event, but to test scenarios that can help inform policy decision making and avenues for further research.


A pizza delivery establishment in Galveston, TX, implemented mitigation measures to lessen the impact of Hurricane Ike in 2008 on their facility. (Source: Robert Kaufmann/FEMA)

## Applying Resilience Scenarios to REMI

This section describes how the resilience scenarios are translated into the REMI model to understand how the estimates of job disruption presented in Section 3 translate into changes in the market value for goods and services sold in a region (i.e., GRP). Calculating the change in GRP is helpful for understanding how economic activity might change in the region following the CSZ event.

Natural disasters can lead to economic disruptions that are difficult to measure prospectively. The scenario provided by DOGAMI allows for calculation of the spatial variation of expected business and job disruption after the CSZ event. The temporal variation of disruption and pathway to recovery after a major earthquake are complex and dependent on the initial response to mitigate additional damage after the event and policy responses to help ensure the viability of business activity in the months after the event occurs.

Planning for post-disaster recovery is critical for economic resiliency. However, this analysis is focused on the potential disruption in GRP in the weeks following the event using a set of simplifying assumptions about the scale of economic disruption described next.

### Modeling Assumptions and Inputs

In addition to the assumptions described in Section 3 made to calculate the expected disruption to employment in the region, translating those results to an input-output model requires making additional assumptions about the appropriate study geography, model parameters, and temporal nature of the impact in order to measure the potential effect on GRP.

#### Geography

A key component of using input-output models for any analysis is to define the appropriate study region. For this study, the REMI model is built to reflect the Portland-Vancouver Metropolitan Area regional economy.[74] This ensures that the model is only accounting for the GRP that is displaced in the study area.

#### Time Horizon

A key limitation of input-output models is that the economic data are represented as annualized values. This can present challenges for modeling the economic effect of earthquakes since the recovery times can vary widely and are dependent on disaster relief and local policies that help increase the flow of capital into the affected region. Based on conversations with the regional stakeholder workgroup, it was determined that it would be speculative to make assumptions about the availability of disaster relief funds, and thus are excluded from this analysis.

One of may sinkholes caused by the 2011 earthquake in Christchurch, NZ (Source: Wikipedia)

To accommodate this restrictive assumption, calculations to changes in GRP are limited to within the first month of the CSZ event. This allows the ability to measure the potential change in GRP associated with the resilience scenarios without also needing to account for long-term disaster relief.

#### Model Adjustments

The dynamic responses from an economic shock rest upon a complicated set of equations, which attempt to calculate how key macroeconomic indicators would shift based on changes in local production. These equations, however, assume that any changes in the macroeconomic indicators occur within a normal business cycle. In order to better align the REMI model with the CSZ event, model adjustments are applied:

*Production costs:* As part of normal cyclical changes in the business cycle, declining economic activity is often associated with declining prices. After the CSZ event, however, the cost of producing local goods and services may remain the same or increase. To account for this, the results net out any decreases in intermediate inputs (capital costs, rent, etc.) in the region resulting from the decline in demand, which implicitly increases to the cost of producing the same amount of goods and service in the region.

*Labor costs*: In addition to increases in material costs, the cost of labor may also increase rather than decrease after the CSZ event. In order to capture this within the model, labor costs[75] are increased by 34 percent,[76] which is a simplifying assumption based on the share of the Portland-Vancouver Metropolitan Area's labor force that crosses a river to access their place of employment.

#### Model Inputs

The inputs for the REMI model rely primarily on the baseline and scenario calculations of jobs from Section 3. Because of the linear relationships that exist with input-output models, these jobs are then translated into gross regional product arising directly from the modeled scenario. From there, total change in GRP associated with each scenario is calculated using the structural relationships within the REMI model.

[74] Typically, this study region also includes Yamhill and Skamania Counties, however they are excluded from this analysis due to the lack of parcel-level disaster estimates.
[75] This is operationalized by changing the labor access index in REMI which captures labor costs and productivity in a region by measuring the efficiency at which local firms can access appropriately skilled employees.
[76] This was determined by using the LEHD Origin-Destination Employment Statistics in combination with GIS data to determine how many employees cross a river based on existing job flows.





### Disruption to the Regional Economy

The outputs from the REMI modeling are displayed in Exhibit 18. These results should be interpreted as the change in GRP relative to the expected baseline disruption. Additionally, the changes in GRP displayed below are annualized totals for the first year after a CSZ event and do not account for the additional economic effects associated with disaster relief. Each of the four policy scenarios modeled is expected to yield some benefit to the region's economy by reducing the amount of total economic activity disrupted after the CSZ event.

Like the results in Section 3, estimated changes in GRP are dependent on the assumptions used to determine which industries are likely to be impacted by the CSZ event and likely to benefit from one of the resilience scenarios. High value-added businesses that are water- or energy-intensive are likely to see the most benefits from strategies that emphasize reinforcing utility infrastructure.

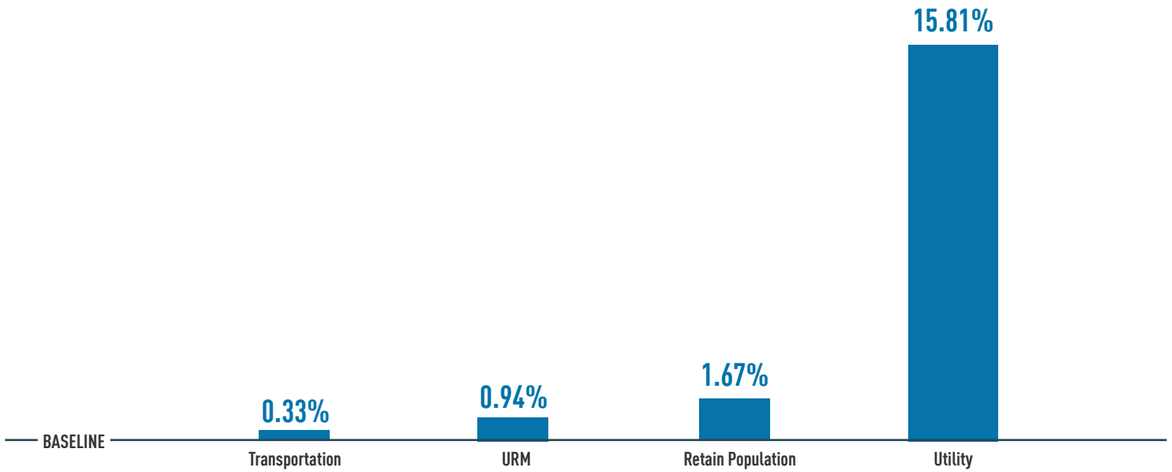
Although the results of this analysis are helpful for prioritizing strategies or policy scenarios, these results should be viewed through the lens of an exploration into the potential economic effects of various resiliency strategies. All these scenarios were implemented without regard to the costs of implementing them. More realistically, the cost to achieve any of these scenario outcomes is likely substantial.

In order to understand the potential trade-offs associated with meeting any of these goals, each scenario should be explored in more detail using a benefit-cost framework. This analysis

Ruins of the Canterbury Television (CTV) building, 2011 earthquake in Christchurch, NZ. (Source: Wikipedia)

cannot speak to the efficiency of the policy scenarios, but only to the extent and distribution of the benefits. A benefit-cost analysis can help determine if the benefits of using public dollars to invest in any of these policy scenarios outweigh the costs. Additionally, these measures of GRP do not directly answer questions about equity and how each policy scenario may improve the well-being of low-income and vulnerable populations in the Portland Metro region.

**EXHIBIT 18 CHANGE IN GRP RELATIVE TO BASELINE DISRUPTION**




Source: ECONorthwest analysis of QCEW, DOGAMI, and City of Portland data using REMI.

This report presents findings that begin to tell a story about how the CSZ event would affect the Portland region's economy. Economic systems are complex, adaptive, and integrally linked to the assets they are built on. The resilience of the economy is — at least initially — only as resilient as the resources that come together to produce economic value: human capital, social capital, physical capital, and natural capital.

This analysis traces the shape of how an earthquake's impacts on buildings (physical capital) and people (human capital) might result in economic disruption immediately following the CSZ event. It offers a high-level perspective on the magnitude and distribution of economic disruption. These results can be viewed as a starting point to answering more complex questions, particularly as better data become available to represent CSZ event impacts to different forms of capital.

A common theme that arose in conversations with businesses was the critical importance of the role social capital may play in minimizing economic disruption and maximizing the potential of economic recovery. Building relationships between the private sector and public sector, and between entities in the private sector, could result in more economically efficient and effective response efforts by reducing barriers to cooperation and enhancing the flow of resources and information when the CSZ event occurs. This has been a key area of research following the Canterbury earthquake sequence in Christchurch, NZ, in 2010-2011.

Relationships between organizations have been found to be an important indicator of an organization's capacity to survive a disaster and adapt to changing conditions. Formal and informal relationships allowed firms to combine resources (e.g., co-location) to navigate resource shortages, address decreases in labor productivity, and redistribute workloads.[77] These factors are not explicitly captured in the resilience factors model used to predict business disruption in Section 3, but could be explored based on the more recent research from Christchurch.

A child & youth program assistant, administers a temperature check at the Center Drive Child Development Center on Joint Base Pearl Harbor-Hickam. (Source: U.S. Navy)

[77] Stevenson et al.

Additional questions with important economic dimensions that arose during interactions with the regional stakeholders and key-informants that could be addressed in future studies include:

- How would variation in the time to restore utilities affect levels of business disruption across the Portland region?
- How would policies that affect rebuilding (e.g., zoning, environmental overlay zones, grandfathering, etc.) following a CSZ event influence the distribution of economic activity and business location decisions across the Portland region?
- How would CSZ-related business disruption over time translate into fiscal impacts for the region's public service providers?
- How does the level of social capital in different contexts (e.g., within neighborhoods, among businesses, between institutions) influence economic resilience and the trajectory of economic recovery?
- How would the CSZ event affect natural capital (e.g., water quality for drinking water and habitat, debris management), and, in turn, how would those impacts affect the trajectory of economic recovery?
- How can planners effectively leverage private business resources to help retain human capital, and how would these policies affect the trajectory of economic recovery?

Each of these questions demand detailed and meaningful study to provide useful insight to policy makers and is not addressed in this report. However, the modeling results produced in this study by combining spatially referenced business data with DOGAMI's parcel-level building damage estimates, layered with other data sets and sources of information, could help address these and other questions at varying spatial scales.

## Lessons from COVID-19

As the research for this study was winding down, the COVID-19 disaster began to unfold. The juxtaposition of these events has led to questions about how the economic effects of society's response to COVID-19 may be similar to economic impacts arising from a CSZ earthquake.

The first thing to recognize is that COVID-19 and the CSZ event are very different types of disasters. The key difference from an economic perspective is the way each disaster affects the underlying stock of capital that economies are built on. In a CSZ event, there would be massive disruption to physical capital. This shock would result in widespread disruption that in some ways might look similar to the COVID-19 stay at home orders: Businesses and schools would temporarily close, and people would be unable to work.

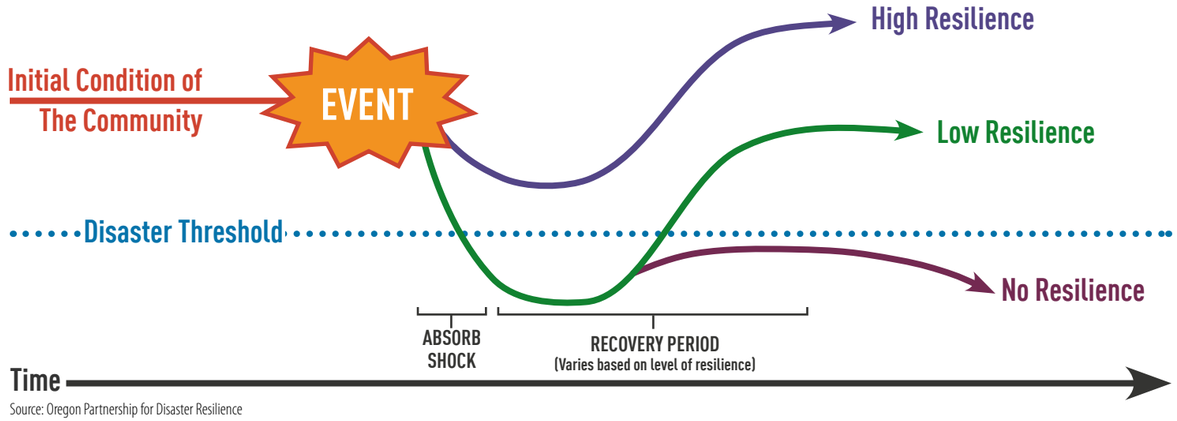
However, unlike with COVID-19, after the CSZ event, many households and businesses would be left without basic infrastructure and lifeline services, such as water, sewer, electricity, and communications. This may restrict the capacity of businesses and individuals to adapt and continue to generate economic activity through remote work and other strategies. Eventually, however, as lifeline services and transportation infrastructure begin to be restored following the earthquake, businesses and consumers would likely re-enter the marketplace, using similar ingenuity and creativity as they have demonstrated during COVID-19.

The response to a CSZ event could functionally parallel the phased response that has unfolded with COVID-19. The University of Oregon Institute for Policy Research and ECONorthwest have identified three distinct phases of the COVID-19 response, beginning with the shutdown, moving into the reopening, and into the recovery period. Business activity is most restricted during the shutdown, when many business are temporarily closed. This is not dissimilar to the temporary closures businesses in many parts of the Portland region would face in response to physical damage following an earthquake. The reopening period represents a period where businesses are able to reopen, but many must make adjustments to their operations, and most would likely be operating in a climate with reduced demand, as well as dealing with operational challenges related to diminished access to labor and some supplies. The recovery period marks the climb back to pre-disruption conditions. Its pace and trajectory depend on the efficiency of government response with both financial aid and organizational leadership, the return of consumer confidence, and market demand.

Exhibit 19 illustrates the potential trajectories an economy might take through these periods. Businesses and communities that have invested in resilience strategies have a higher likelihood of experiencing a smaller initial shock and a more rapid return to initial conditions. In the best case, these businesses and communities are positioned to improve their economic position through two mechanisms. The first is that they may be in a better position relative to less-prepared entities to capture demand and revenue. The second is that they may have the resources and capacity to embrace new opportunities created by the disruption or use the disruption to become more efficient.

Another point of comparison that may provide valuable insight into how policy makers can leverage current experience to prepare for a CSZ event is how economic disruption falls disproportionately on vulnerable populations. Among the economic sectors that have been most disrupted by COVID-19 are tourism, service, and hospitality, which employ many low-wage workers comparatively less prepared to ride out temporary disruptions in income. A CSZ event would also immediately disrupt this sector and these workers, with long-term disruption potential. Remote work is more available for middle- and upper-income workers, who are already more resilient to economic disruption. As with COVID-19, a CSZ event is likely to further entrench already-existing inequalities. The tools available to mitigate this with COVID-19 are likely to be relevant in the response to a CSV event.

EXHIBIT 19 RESILIENCE AND RESPONSE TRAJECTORIES




Source: Oregon Partnership for Disaster Resilience

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