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The Impact of Spatial Dependency on Earthquake Risk Analysis

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Natural-hazard mitigation strategies rely on vulnerability and hazard information that, when combined, provide an assessment of the risk for a parcel of land, neighborhood, community, or region. Risk analyses for earthquake hazards are populated with probabilistic estimates of destruction of the built environment for determining the expected payoff of a loss-reduction choice. However, the expected outcomes contain uncertainties large enough to cause choice ambiguities for policy evaluation. One type of problem with existing loss estimation methods is that they assume building sites are conditionally independent of one another, given the location and magnitude of an earthquake. But it is clear (from the continuity properties of wave propagation) that peak ground acceleration levels at sites close to one another must surely exhibit some degree of positive correlation. This spatial dependency tends to increase the variance of realized damage costs in large earthquakes.

In a case study in Memphis, TN, we evaluate the benefits and costs of a recently implemented seismic building standard for new commercial and industrial structures. We outline a probabilistic risk model for analyzing the potential damage costs of liquefaction, which is a spatially dependent natural hazard resulting from large earthquakes. We estimate the probable damage costs for earthquake-triggered liquefaction and the risk of investing in mitigation based on the new building standard. Inputs to the model from the probabilistic hazard assessments will affect the expected payoff of a choice scenario. For example, one uncertainty for a mitigation strategy is related to the spatial distribution of the liquefaction hazard and the application of the new building standard. Since the standard only applies to new construction and because these buildings are intermingled with existing structures that are not subject to the standard, a mitigation strategy that applies the building code must consider both types of structures

in areas subject to liquefaction. A risk analysis that assumes spatial independence for the region, and considers only an evaluation of new structures, most likely, will underestimate damage costs. Allowing for spatial dependency shows an increase in the earthquake risk to the Memphis region and suggests the need to expand the building standard to existing structures. Repeated simulations at regional scale using the model yield a sampling distribution (histogram) of realized benefits and costs for different community planning horizons. These values represent maximum likelihood estimates of an exceedence probability (EP) function of damage costs for a set of strategy and information parameters.