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Causal Inference in Geoscience: An Application to Induced Seismicity

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ABSTRACT

Saltwater disposal has been identified as the dominant causal factor that contribute to induced seismicity. Physical models rely on mechanistic understanding to infer causality where they evaluate various conditions for fault slips albeit with a high degree of uncertainty due to sparse data and subsurface heterogeneity. Given these uncertainties, statistical analysis is designed to measure statistical associations in the observed data with parametric regression models and interpret the significance of specific coefficient as evidence of causation. However, it is often difficult to interrogate the coefficients between different statistical models as the coefficients hold different implications. We propose a causal inference framework with the potential outcomes perspective to explicitly define what we meant by causal effect and declare necessary assumptions to ensure consistency between models for model comparison. The proposed workflow is applied to the Fort Worth Basin of north-central Texas with the area of interest is discretized into non-overlapping grid blocks. Two statistical methods are employed to test the significance of the causal effect between the presence or absence of saltwater disposals and the number of the earthquakes and to estimate the magnitude of the average causal effect. In addition, our analysis is repeated for different grid configurations to directly assess the sensitivity of statistical results. We have identified a stable and statistically significant causal relationship between the presence of saltwater disposals and the number of earthquakes and have estimated that there are, on average, 13 more earthquakes occurring in grids with saltwater disposals.

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