Coastal Flood Risk Assessment and Dynamic Adaptation under Climate Change Uncertainty

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Abstract

Coastal flooding is a frequent and devastating natural hazard caused by a coastal process. Climate change poses significant challenges and impacts on coastal communities. Efficient adaptation strategies are crucial to address future flood risks. This thesis aims to assess coastal flood risk under climate change and identify optimal decisions of structural adaptation strategies to minimize flood risk. This thesis developed an integrated modeling framework that couples stochastic tropical cyclone model, storm surge model, inundation model, climate change projections, coastal defenses, and adaptation measures. This model incorporates scenario analysis, risk assessment, and cost-benefit analysis to quantify the flood damage and the effectiveness of adaptation strategies. Moreover, considering the uncertainty of climate change, this thesis proposed a dynamic adaptation decision-making model for coastal protection systems by minimizing coastal flood risk to identify optimal investment timing and the size of the structural infrastructure. Furthermore, this thesis investigated homeowners' preferences for coastal flood risk mitigation under ambiguity by coupling flood simulations and stated preference experiments with decision models.

According to this research, some findings are derived. First, the results show that coastal flood risk will increase dramatically as combined impacts of intensified storm surges and sea level rise, due to climate change. Without adaptation measures, the damages and casualties from flood have the potential to increase several folds in the coming decades. Second, despite the predicted decrease in future population numbers in Osaka Bay, the number of flood

casualties is expected to grow due to the increasing aging. Therefore, it is important for governments and communities to take the specific needs and vulnerabilities of the elderly population into account when planning and implementing flood risk management and adaptation strategies. Third, the results indicated that raising the height of existing dikes can reduce flood risk effectively. The benefits and costs depending on the elevated height and the discount rate. Using a traditional cost-benefit analysis, this study has shown that that upgrading by 1m the height of existing dikes to adapt to climate change is the most cost-effective strategy for Osaka Bay. Fourth, uncertainty about climate change and the time lag of adaptation measures pose significant challenges to adaptation decision-making. The results indicate that a dynamic adaptation decision model is more effective in decreasing annual coastal flood risk costs than a static one in the context of climate change uncertainty. Under the RCP 8.5 scenario, the dynamic model decreases annual risk costs by 5-10% compared to the static one. Furthermore, the critical threshold of the adaptation investment highly depends on time lags and discount rates. As the time lag increased, the benefits of adaptation measures significantly diminished. Fifth, the analysis indicates that an ambiguity premium is not negligible in economic efficiency or cost-benefit consideration of risk mitigation policies. Rather, they are distributed extremely in some areas of higher expected loss from coastal inundation. This suggests that ambiguity premiums should be measured for planning and implementing coastal flood risk mitigation policies.

While the research focuses on Osaka Bay, the methodology developed in this thesis contributes to coastal flood risk assessment and dynamic adaptation under climate change uncertainty. And some of the findings apply to other coastal regions threatened by storm surges and sea level rise.