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Economic evaluation of climate risk adaptation strategies: Cost-benefit analysis of flood protection in Tabasco, Mexico

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RESUMEN

Las pérdidas económicas debidas a desastres naturales se han incrementado en las últimas décadas como resultado del desarrollo socioeconómico y probablemente del cambio climático. Las proyecciones indican que esta tendencia al alza continuará, lo cual resalta la necesidad de adoptar estrategias de adaptación. Esto a su vez pone de manifiesto la necesidad de establecer mejores estrategias de adaptación adecuadas para hacer frente a los embates inciertos del cambio climático. El presente estudio muestra cómo puede aplicarse una cascada de modelaciones de riesgo y desastres, y un análisis de costo-beneficio, para obtener un primer indicador de estrategias de adaptación eficientes desde el punto de vista económico. Este enfoque se aplica a un análisis de riesgos de inundación y a la conveniencia de contar con protección contra inundaciones en el estado de Tabasco, México, el cual padece graves inundaciones casi anualmente. Los resultados muestran que el daño anual esperado por inundaciones costeras se incrementará de los actuales USD 530 millones a USD 4120 millones en 2080 como resultado del desarrollo socioeconómico y el cambio climático. En cuanto al daño estimado por inundaciones fluviales, se espera que se incremente de los actuales USD 1790 millones a USD 10 600 millones en 2080 si no se establecen medidas de adaptación. Con base en el análisis de riesgo y costo-beneficio de la construcción de infraestructura contra inundaciones, establecimos en al menos 100 años los estándares óptimos de protección desde el punto de vista económico para ambos tipos de inundación. Nuestras principales conclusiones son robustas con relación a la incertidumbre sobre los efectos del cambio climático en riesgos de inundación, los daños indirectos causados por éstas, la extensión de los terrenos inundables y la tasa de descuento social adoptada. Analizamos la forma en que nuestro enfoque multidisciplinario puede ayudar a los encargados de la toma de decisiones respecto al manejo de riesgos de inundación, y la manera en que investigaciones venideras pueden ampliar nuestro método a análisis locales específicos, que son necesarios para desarrollar planes de adaptación a nivel local.

ABSTRACT

Economic losses as a result of natural hazards have been rising over the past few decades due to socio-economic development and perhaps climate change. This upwards trend is projected to continue, highlighting the need for adequate adaptation strategies. This raises the question of how to determine which adaptation strategies are preferred to cope with uncertain climate change impacts. This study shows how a multi-disciplinary cascade of hazard modelling, risk modelling, and a cost-benefit analysis can be applied to provide a first indicator of economically efficient adaptation strategies. We apply this approach to an analysis of flood risk and the desirability of flood protection in the state of Tabasco in Mexico, which faces severe flooding on an almost yearly basis. The results show that expected annual damage caused by coastal flooding is expected to increase from 0.53 billion USD today up to 4.12 billion USD in 2080 due to socio-economic development

and climate change. For river floods, expected annual damages are estimated to increase from 1.79 billion USD up to 10.6 billion USD in 2080 if no adaptation measures are taken. Based on the estimated risk and cost-benefit analysis of installing flood protection infrastructure, we determined the economically optimal protection standards for both river and coastal floods as at least 100 years, if we take into account climate change. Our main conclusions are robust to key uncertainties about climate change impacts on flood risks, indirect damage caused by floods, the width of the protected floodplains, and the adopted social discount rate. We discuss how our multi-disciplinary approach can assist policy-makers in decisions about flood risk management, and how future research can extend our method to more refined local analyses which are needed to guide local adaptation planning.

Keywords: Climate change adaptation, cost-benefit analysis, flood risk, natural hazards, risk and uncertainty.

1. Introduction

Economic losses from natural disasters have been increasing during the past few decades in many areas around the world (IPCC, 2012). This upwards trend in losses has been mainly attributed to socio-economic developments, such as economic and population growth in disaster-prone areas, which have increased the exposure of properties that can be damaged by natural hazards over time (Bouwer, 2011). Natural disaster damages are the outcome of a complex interplay of these changes in exposure with changes in vulnerability, caused by socio-economic development and decisions, and changes in hazard, which can be influenced by climate change or human interventions in the hydrological system. These interactions make it complicated to draw clear-cut conclusions on trends in the causes of natural disaster losses. It cannot be ruled out that climate change has contributed to past natural disaster losses (Estrada et al., 2015). Moreover, future natural disaster losses are expected to increase in many regions around the world (Hirabayashi et al., 2013). Future risks are projected to increase due to a combination of continued population and economic growth and climate change, which can cause increases in the frequency and/or intensity of extreme weather events, such as more severe droughts, storms, and floods (IPCC, 2014).

The projected increase in risks from natural disasters can be limited by implementing adaptation measures, such as installing protection infrastructure and adjusting buildings so they can better withstand the disaster. A key question is thus how to identify adaptation measures that are suitable for the local scale and which generate an adequate economic return. An interdisciplinary approach of hazard assessment, risk assessment, and economic cost-benefit analysis (CBA) of adaptation measures can provide insights for identifying economically efficient adaptation strategies to manage natural disaster risk, as will be illustrated in this study. In short, natural hazard modelling involves estimating potential hazard characteristics in terms of physical variables, such as potential flood extents and inundation depths in an area (e.g. Chen et al., 2016). As a next step, risk modelling aims to estimate the societal impacts, usually in terms of property damages, that are associated with specific hazard characteristics; for instance, the potential damage that a flood can cause in a certain geographical area (Grossi and Kunreuther, 2005). The low-probability nature of natural disasters generally means that few historical data exist on disaster impacts, which explains why most natural disaster risk assessments rely on models to estimate how hypothetical hazard characteristics translate into monetary damages. This can be carried out in a modelling framework, often using a Geographical Information Systems (GIS) environment that combines hazard-modelling output with information about exposed land use or property values and assumptions about their vulnerability, i.e. their susceptibility to damage. Common outputs of risk models include the potential direct property damage and/or indirect business interruption damage that a particular hazard can cause (such as a flood with a certain probability), or the expected annual damage (EAD) of a hazard (e.g. Meyer et al., 2013). When such risk indicators are presented at a high spatial resolution they can be used for indicating where risk management measures, for example flood protection infrastructure, should be prioritised (Zerger, 2002). Moreover, risk modelling can deliver key inputs for CBA of disaster risk reduction strategies by estimating the potential benefits of such measures, in terms of the reductions in EAD they deliver, as shown by Michel-Kerjan