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Copenhagen, Sea Level Rise and Future Storm Surge Risk: Exposure Analysis and Simulation of Economic Loss

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This OECD study investigates the current and future exposure of the city of Copenhagen (København), Denmark, to sea level rise and storm surges. Copenhagen is a low-lying city, with the highest ground around 45 m above sea level. While its geography means that it is currently at a relatively low risk of coastal flooding, it is vulnerable to storm surge events associated with storms in the Baltic Sea. It is estimated that today a storm surge of amplitude 150 cm (above mean sea level) will be seen approximately once every hundred years. By raising the water level of storm surge events, anthropogenic sea level rise has the potential to significantly increase these risks.

We focus here on high return-period storm surge events, which are less likely to be defended against. By 2030, in an unchanged city, the population exposed to a 100 yr event could rise from around 29,100 to 32,300 - 34,500 people because of sea level rise. By 2100, it could reach 42,400 - 68,500 people, or around 3% of the population. The exposed insured value of property could rise from EUR7.1 billion, to EUR8.1-8.7 billion by 2030, and EUR11.0-17.9 billion euros by 2100. Taking into account population and economic projections, exposure to the 100-yr event could reach in 2100 around 45,800 - 74,000 people and an insured value of property of EUR39.6-64.4 billion.

From exposure and vulnerability curves, potential losses caused by events with dif-

ferent sea levels (or, equivalently, with various return times) can be estimated as a function of mean sea level rise. Assuming that the city is only protected against events that are more frequent than once every 100 years, for example, the 100-yr event would cause today direct losses amounting to about EUR2.0 billion. Assuming that protection is upgraded to follow sea level rise and maintain the flooding probability, these losses would reach EUR3.7 billion in case of a 50cm sea level rise and EUR5.1 billion with a 1m sea level rise, a 85 and 160% increase, respectively. These figures show that sea level rise could increases flooding risks in a significant manner.

The ARIO model is then used to assess how these direct losses would translate into total losses, taken into account indirect effects and economic feedbacks. As an example, an event with sea level 2m above current level would lead today to direct losses amounting to about EUR3.7 billion. According to ARIO, the corresponding indirect costs would be EUR82 million in lost value added in different economic sectors, and EUR300 million in lost housing service, and 6,000 lost jobs over the short term. These indirect losses are found to increase in a strongly nonlinear manner with respect to direct losses. Return time of various events can then be related to direct and indirect losses. For the 100-yr event, for instance, total losses (direct plus indirect) are estimated at EUR2.2 billion in the absence of sea level rise. These losses may reach EUR4.1 billion with a 50 cm sea level rise, a 90% increase, and EUR5.7 billion with a 1m SLR, a 160% increase.

Up until now, the risk of flooding in Denmark has been considered to be very low, as the areas worst affected by storm surges are not densely populated and are well protected. This study has shown that, for Copenhagen, the risks could rise considerably over the coming decades. Of course, sea level rise will lead to adaptation investments to protect the city. It must be noted, however, that protection is effective up to a given level, defined at the protection design. Above this level, protections are overtopped and their protection efficiency becomes null. This residual risk, together with the failure risk, has to be taken into account in the decision-making process.