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"Living on the edge": Estimating the economic cost of sea level rise on coastal real estate in the Tampa Bay region, Florida

Xinyu Fu [a], Jie Song [a], Bowen Sun [b], Zhong-Ren Peng [a, *]

[a] Department of Urban and Regional Planning, University of Florida, Gainesville, USA
[b] Institute for the Development of Central China (IDCC), Wuhan University, Wuhan, China

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ABSTRACT

Climate change and especially sea level rise are posing unprecedented pressure on coastal communities through enhanced coastal flooding and saltwater intrusion. Thus, adapting to its impacts has drawn global attention. Since the cost-efficiency of adaptation alternatives is crucial in decision making, accurately estimating the economic cost of sea level rise is an imperative task for coastal planners and managers. This study employed a spatial hedonic approach to estimate the economic cost due to inundation by future sea level rise. The applied methodology provides better estimates of the economic losses due to sea level rise by accounting for lost coastal amenities, and the results generated can also be utilized for cost-benefit analysis. In 2050, it is estimated that the inundation of 3-foot sea level rise could cost Hillsborough and Pinellas County over 300 and 900 million dollars respectively for the real estate market alone. Local coastal planners and managers may find this methodology useful in estimating the potential economic cost due to sea level rise and support making adaptation decisions. We also stressed the importance of such studies to support local decision making and enhance adaptation planning for the climate change and sea level rise in the coastal communities.

1. Introduction

Coastal regions in the US are highly valuable, yet they are also extremely vulnerable to climate change. Coastal counties, which account for less than 10 percent of the nation's total area, accommodate over 39 percent of the national population (NOAA, 2013). Also, coastal regions largely drive the US economy by contributing to 37 percent of the US employment and 42 percent of the national GDP (Kildow et al., 2014). People have been continuously attracted to the coast because of its booming economy and favorable life quality (Kron, 2013), and such a trend is expected to continue in the upcoming decades (NOAA, 2013).

With the rising sea, coastal planners and managers are facing the greatest challenges to manage growing coastal communities. The record breaking coastal disasters (e.g., Hurricane Katrina in 2004 and Sandy in 2012) have already demonstrated high socio-economic vulnerability in coastal areas. In addition, sea level rise would significantly exacerbate the consequences of these coastal hazards. Studies found that even the modest scenario of sea level rise combined with coastal hazards could result in catastrophic impacts (Frazier et al., 2010; Shepard et al., 2012; Tebaldi et al., 2012). Although there is still debate on how much sea level will rise, it is almost certain that sea level has been rising and this trend will continue. Thus, studying its possible impacts and identifying the optimal adaptation strategies have gained tremendous popularity during the last decades.

Generally, sea level rise affects coastal regions by salt water intrusion, coastal erosion, wetland reduction, and inundation (Nicholls, 2011). The impacts of inundation have drawn relatively more attention largely because, combined with coastal hazards, inundation consequences are more immediate and visible, and significant amount of money have been paid for its lessons. By adopting adaptation strategies, the inundation risk due to sea level rise can be effectively reduced. However, the catastrophic impacts of recent storms (e.g., Hurricane Sandy in 2012) still demonstrated the lack of implementing adaptation measures, and meanwhile reinforced their necessity (Hinkel et al., 2014; Neumann et al., 2014; Swiss Re, 2013). Nicholls and Cazenave (2010) asserted that the adoption of adaptation strategies was highly technical and

* Corresponding author. Department of Urban and Regional Planning, College of Design, Construction, and Planning, University of Florida, P.O. Box 115706, Office: 462 ARCH, USA.
E-mail address: zpeng@ufl.edu (Z.-R. Peng).

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sociopolitical, and it required plausible cost-benefit analysis of desirable adaptation alternatives, which most local planning entities lacked such analysis. Also, the uncertainty of future sea level changes adds an additional layer of complexity into local decision making. As coastal planners rely heavily on the cost-benefit analysis to make adaptation decisions, accurately estimating the economic impacts of sea level rise has important meanings. In this paper, we first summarize the contemporary literature on the economic cost of sea level rise and their implications to coastal planning and management. It is followed by a case study to estimate the economic cost of inundation due to future sea level rise on the real estate market in a metropolitan area in Florida. Finally, we conclude with planning suggestions for coastal managers and future researches.

2. Economic cost of sea level rise

Research in estimating the economic cost of sea level rise is still scarce compared to related studies on coastal hazards. Sea level rise is known to be a slow-ongoing natural process, yet human-induced. However, the impacts of sea level rise are usually negligible in the short-term but when considered with coastal hazards the combined impacts can be catastrophic to coastal communities. Now, many coastal communities have even considered sea level rise to be one independent coastal hazard in their plans in the US (Fu et al., 2016). Thus, in recent years, research proliferated in studying the socioeconomic impacts by considering future sea level rise and coastal hazards together, which are majorly associated with coastal flooding (Hinkel et al., 2014; Lichter and Felsentein, 2012; Song et al., 2016; Woodruff et al., 2013) and storm surge events (Frazier et al., 2010, Hallegatte et al., 2011; Neumann et al., 2014; Shepard et al., 2012; Tebaldi et al., 2012). Although these studies provided a general picture of what future impacts could be, the marginal impacts on coastal hazards are only one of the many consequences due to sea level rise so that the results of these studies are not exhaustive. Also, the models employed by these researches were usually data intensive, and local communities might lack the modeling talents, which impeded such economic analysis to take place at local levels. These studies usually delineated hazard zones under arbitrary sea level rise scenarios with coastal hazards, and few of them provided numerical estimates on possible impacts. Thus, due to the above reasons, local governments could hardly translate sea level rise adaptation agenda into action based on the results of these studies.

Other major studies focused on the inundation impacts of future sea level rise alone on various sectors. One of the earliest serious studies estimated the cost of dryland protection, and identified the optimal protection ratio by balancing gains and losses (Fankhauser, 1995). Hoozemans et al. (1993) concentrated on the vulnerability of global population, wetlands, and rice production by estimating the losses due to sea level rise. Yohe et al. (1996) studied the economic impacts of sea level rise on developed properties along the shoreline on the city level. Later studies included more sectors, such as agriculture, forestry, ecosystem, social impacts, and water resources, for more exhaustive estimates of the economic losses of future sea level rise (Anthoff et al., 2010; Hinkel et al., 2014; Tol, 2002a, 2002b). These early studies were later argued to be insufficient because they only estimated the direct impacts of sea level rise. The indirect impacts are defined as the ripple effects onto the economic system by direct impacts. For example, assuming a house is permanently under water due to sea level rise, the structure and land loss is considered as a direct impact, but the losing values of its service for accommodating is considered as an indirect impact. The computable general equilibrium (CGE) models were widely utilized to calculate the indirect impacts of sea level rise (Bigano et al., 2008; Bosello et al., 2012, 2006, 2007). However, these studies are all conducted on larger scales (i.e., national and global level) where aggregated economic data are usually available to build CGE models. Such models are usually impossible to be built at locally disaggregate levels due to data unavailability. Local coastal planners, therefore, could hardly employ such methods to support decision making.

Based on the advancing methodologies in estimating the economic cost of sea level rise, many have also studied the cost-efficiency of adaptation strategies for sea level rise on the national and global scale (Sugiyama et al., 2008; Tol, 2007; Tol et al., 2008). But researches on the local level are comparatively scarce primarily due to data limitations. Since the local level is where impacts are felt and adaptation decisions are made, local adaptation planning for sea level rise is gaining increasing popularity. However, as sea level rise can affect coastal communities in various ways, either directly or indirectly, conducting a holistic analysis of the economic cost of sea level rise could hardly be accomplished. Thus, local studies majorly focused on a much narrower scope such as natural hazards (Tebaldi et al., 2012; Frazier et al., 2010; Hallegatte et al., 2011) and real estate (Bin et al., 2011; Yohe et al., 1996). In this study, we focus on the economic cost of inundation due to sea level rise on the real estate properties. The existing approach of estimating the economic cost usually employs the properties' market-assessed values but this approach is no longer accurate for the case of sea level rise as argued by Yohe (1991). It is because the traditional approach does not account for the lost coastal amenities (e.g. sea view, accessibility to beaches, and port infrastructures) of the properties that would be permanently under water, and the transferring values of the coastal amenities due to shoreline changes by sea level rise. Thus, we aim to provide a better estimate of the inundation loss on real estate properties due to sea level rise that accounts for the losing coastal amenities in a metropolitan area that has not been studied before.

3. Methodology

We employed the hedonic price model to estimate the economic loss due to inundation by sea level rise. The hedonic modeling was commonly used in disentangling the impacts of the heterogeneous characteristics of properties as reflected in the price differentials (Bin et al., 2008, 2011; Gopalakrishnan et al., 2011, Hamilton, 2007; Jin et al., 2015; Landry and Hindsley, 2011; Parsons and Powell, 2001; Rambaldi et al., 2013). The general property characteristics fall into structural (S), location (L) and environmental (E) categories. Below is a typical hedonic price model:

$$\ln P = \alpha + \beta S + \gamma L + \theta E + \varepsilon \quad (1)$$

where ln P is the log of the property value; α is the constant; β, γ and θ are variable coefficients to be estimated; S represents structural variables (e.g., number of bedrooms), L represents location variables (e.g. floodplain), and E represents environmental variables (e.g., distance to coast); ε is the error term.

The major incentive for using the hedonic price function is to estimate the value of coastal amenities. As the properties that are closer to the coast are commonly much more expensive than the similar properties inland, directly using the total value of the lost properties due to inundation would overestimate the economic cost. It is because the estimation still includes the value of coastal amenities that are already lost. If the property is permanently under the water due to sea level rise, the premium value paid for the proximity to the coast should be purged for more accurate estimate of the net loss. Also, since the coastline shifts inland due to sea level rise, the lost amenities value will also be transferred to inland