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Assessing sea level rise costs and adaptation benefits under uncertainty in Greece

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ABSTRACT

Although sea-level rise (SLR) is not the only driver of coastal change, it is expected to radically alter the living conditions and prosperity of coastal communities in the decades to come. The economic assessment of sea level rise impacts and of coastal adaptation measures proves to be rather demanding due to the fact that these are complex phenomena, affected by both global conditions and local parameters. All these factors add to the uncertainty involved in climate change assessments, in general, and in SLR impacts in particular, creating significant ambiguity during the policy-making process. This paper wishes to contribute to existing literature by exploring modern management tools for assessing the economic impacts of SLR and the effectiveness of proactive coastal adaptation under uncertain conditions. To this end, first, the economic damages from long-term shoreline retreat and land inundation for scenarios of 0.5-m and 1-m SLR up to 2100 are estimated for the Greek coastal zone, both deterministically and probabilistically. The results indicate that probabilistic damages are lower than the deterministic ones by 6%, on average. However, the uncertainty results in a range of probable values, which are 45% lower and up to 40% higher than the deterministic estimates. Second, and most important, the application of real options valuation (ROV) in the economic assessment of adaptation measures is illustrated using four specific case sites. The findings show that ROV provides decision-makers with the flexibility to 'adjust' the so-called hard engineering structures to future SLR conditions by keeping all options (i.e. scale, deferral, acceleration or abandonment) open till further knowledge is gained. In this way, ROV creates an additional value that cannot be captured by 'conventional' valuation methods and, thus, it offers the potential to maximize long-term benefits for the society by making efficient use of fiscal resources for adaptation strategies.

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1. Introduction

The relocation rate of human activities from the inland to the coastal areas has been described as one of the greatest human

migrations of modern times (Tibbetts, 2002). The importance of coastal resources for the prosperity of human societies is amply demonstrated through the notion of ecosystem goods and services (Turner et al., 2001; Garpe, 2008; Kontogianni et al.,

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2010). A general categorization of coastal goods and services is presented in Table 1.

Nevertheless, following the dominant pattern of industrialization and economic growth, the coastal areas have been gradually transformed into contested domains of intense pressures exerted by anthropogenic activities such as inter alia rapid urban expansion due to growing population, increased mobility and transport infrastructure, tourism, fishing, aquaculture and habitat loss. (EEA, 2006)

Nowadays, it is widely accepted that climatic change accentuates the pressures onto oceans and coasts bringing to the fore one of its most critical impacts, the global rise of mean sea level (SLR) (Nicholls et al., 2007; Bindoff et al., 2007). The primary contributing factors for SLR have been cited as: (a) thermal expansion of oceans, (b) melting of glaciers and loss of the ice masses in Greenland and Antarctica and (c) changes in terrestrial water storage (Pokhrel et al., 2012; Wada et al., 2012), with thermal expansion of oceans being expected to be the dominating factor (Meehl et al., 2007). As a result of SLR and the future land use pattern of coastal areas, there will be serious risks to coastal communities and ecosystems in the future due to increasing flood frequency, inundation, coastal erosion, rising of water table, and saltwater intrusion (Nicholls, 2003; Kulpraneet, 2012). These changes will in turn have major socio-economic and environmental implications and, thus, the degree of damages from SLR will depend on the adaptability of the affected man-made and natural systems.

However, there is significant uncertainty about exactly how the climate will change in the future and what will be the actual effects to SLR. According to Forest et al. (2002), the two most important uncertainty factors associated with climate change and, thus, the SLR risks are climate sensitivity (i.e. the increase in global mean temperature in response to an increase of atmospheric concentrations) and the rate of heat uptake by the deep ocean. Without taking into consideration the potential future acceleration of ice sheet dynamics, Meehl et al. (2007) assert that global warming could increase sea level from 0.18 to 0.59 m by the end of the 21st century (2090–2099).

High-end scenarios give us a better understanding of the potential contribution of ice sheet dynamics to accelerated sea level rise. Dasgupta et al. (2007) uses such low-probability/high-impact scenarios to show that an unexpectedly rapid breakup of the Greenland and West Antarctic ice sheets might produce a 5 m SLR. NRC (2011) points out that by 2100 the combined impact of thermal expansion of ocean water and ice loss from glaciers and small ice caps is likely to raise sea level by at least 60 cm. Nicholls et al. (2011) estimated the sea-level rise by 2100 between 0.5 and 2 m for a temperature rise of 4 °C or more over the same time frame due to the response of the large ice sheets of Greenland and west Antarctica. Lately, multi-gas emission scenarios known as Representative Concentration Pathways (RCPs) have been used to provide a range of possible futures for the evolution of atmospheric composition (Meinshausen et al., 2011).

Bearing in mind the above remarks, it becomes evident that, policy formulation for facing SLR challenges becomes a complex issue due to the uncertainty involved. The effect of the parameters affecting climate change in general and SLR in particular, will become known through the passage of time and, at least partially, the uncertainty will be resolved. Of course, the value of waiting for additional information depends on the extent to which the uncertainty affects the cash flows of climate adaptation investments, how far in the future the uncertain event is, and the likely quality of the information that will be gained by waiting (IEA, 2007). If it is anticipated that uncertainty will never be removed entirely, then it is preferable to take early action on the basis of a significantly higher cost of damages compared to the cost of abatement (Stern, 2007) and the precautionary principle.

Thus, it is more than just necessary to quantify the uncertainty in the parameters involved in order to facilitate SLR and climate change policies. Toward this direction, the aim of this paper is to contribute to the existing literature by implementing Monte Carlo simulations and real options valuation in estimating SLR costs and adaptation benefits under uncertainty in Greece. The paper builds on previous research of Kontogianni et al. (2012) who estimated the damages of SLR on the Greek coastal zone using deterministic approaches. The deterministic models provide estimates taking into consideration the initial conditions of a specific set of parameters. Within the present analysis, we perform a probabilistic estimation of SLR costs through the implementation of Monte Carlo simulations to highlight the range of probable cost outcomes. Probabilistic models such as Monte Carlo simulations provide estimates utilizing values of a specific set of parameters derived by probability distributions. Based on four specific coastal adaptation cases, we further apply real options valuation to obtain a more sophisticated treatment of uncertainties in SLR adaptation strategy.

The general analysis follows the direct cost approach, which is usually contrasted to the economy-wide assessment of climate change impacts based on either CGE or IA models (Bosello et al., 2007). Direct cost approach is a bottom-up, cost accounting method that uses engineering cost data to analyse all potential cost components for an activity in a partial analysis context. By ignoring sectoral interdependencies, the direct cost method underestimates the true welfare losses of climate change in a top-down, general equilibrium context

Table 1 – Categorization of goods and services in the coastal environment.

Supportive services	Regulating services
1 Biochemical cycling	1 Atmospheric regulation
2 Primary production	2 Local climate regulation
3 Food web dynamics	3 Sediment retention
4 Diversity	4 Biological regulation
5 Habitat	5 Pollution control
6 Resilience	6 Eutrophication mitigation
Provisioning services	Cultural services
1 Food	1 Recreation
2 Inedible resources	2 Aesthetic values
3 Genetic resources	3 Science and education
4 Chemical resources	4 Cultural heritage
5 Ornamental resources	5 Inspiration
6 Energy resources	6 The legacy of nature
7 Space and waterways	

Source: Kontogianni et al. (2012) as adapted from Garpe (2008) and MEA (2005).

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