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Investing in adaptation: Flood risk and real option application to Bilbao

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ABSTRACT

Investment decisions in adaptation are usually made under significant uncertainty due to climate change and socio-economic trends. In this study, we propose three ways to incorporate climate and socio-economic uncertainty into the assessment of an adaptation infrastructure designed to cope with flood-risk in the city of Bilbao. First, we use stochastic modelling to estimate the present value of expected damage over a time period, considering that extreme events may increase in the future. Second, we develop an additional calculation that incorporates two risk measures used in financial economics: Value-at-Risk and Expected Shortfall, the latter being a less common but better risk indicator. Third, we illustrate a case of Real Options Analysis (ROA) in which a binomial tree is used to study whether the best decision at present is to invest now or to delay the investment decision.

1. Introduction

There is limited evidence and great uncertainty about future rainfall under climate change (Jiménez Cisneros et al., 2014). Projections should be treated with caution, even though they point to more frequent extreme rainfall (Whitfield, 2012; Jiménez Cisneros et al., 2014). In fact, some patterns of change have already been detected. For example, Schönwiese et al. (2003) examine the change of extreme monthly precipitation in Europe, concluding that in some mid-latitude regions like Europe (except Southern Europe) earlier assumptions can be confirmed that a positive trend in winter precipitation is linked to a dramatic increase in the frequency of extreme wet months, which may have serious consequences with respect to flooding and soil erosion. Milly et al. (2002) found that floods with 100-year return periods increased significantly during the past century in several large basins in the USA. In Europe, extreme precipitation is also likely to increase, leading to more frequent, more intense flood events. Specific studies for the Basque Autonomous Region forecasted significant increases in extreme precipitation, in the areas prone to be flooded and in the damages as a consequence of flood events (Basque Government, 2011). Special attention should be paid to these events as floods are already not only the most common extreme event but also the costliest (Ciscar et al., 2011; Whitfield, 2012; Rojas et al., 2013).

Flood hazard is currently determined to a great extent by local factors, such as land use (Whitfield, 2012). During the 20th century, flood-damages rose as a result of a greater exposure and vulnerability of assets and people, and the contribution of socio-economic factors to flood risk has been estimated to be equal to or even greater than that of climate change alone (Jiménez Cisneros et al., 2014; Kovats et al., 2014). In this context, future risk will depend largely on the baseline situation, but also on the land-use and adaptation policies set up in the short and medium term.

In this context, decisions to invest in adaptation need to deal with a major issue: uncertainty (Hallegatte, 2009). In an environmental modelling framework, three dimensions of uncertainty need to be considered (Refsgaard et al., 2007): first, the nature of uncertainty, i.e. whether it is due to incomplete knowledge or is the result of natural variability; second, the type of uncertainty, e.g. statistical uncertainty or that related to scenarios; third, the source of uncertainty, i.e. whether it is related to the context under study, to input data, etc. Moreover, cumulative uncertainty is most likely to occur under climate change, where every step of each dimension will add uncertainty to the next one (Markandya, 2014). In summary, to assess investments in adaptation, one must acknowledge that there will be uncertainty related to the context (the study area), the climate modelling, the impact modelling, the socio-

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economic scenarios, etc. Saint-Geours et al. (2015), for example, develop an interesting assessment of the impact of uncertainties from different sources on the outcomes of a cost-benefit analysis (CBA) of flood control structural measures in France. They found that all uncertainty sources matter and contribute to the CBA variance. Therefore, the development of approaches that account for uncertainty can be considered as one of the main priorities in the field of the economics of adaptation to climate change (Hunt and Watkiss, 2010).

In fact, uncertainty is extensively addressed in the fifth and latest IPCC Assessment Report (AR5) (IPCC, 2014) and new approaches are emerging to provide a response to new complex challenges. As theory shifts towards practice, adaptation has been acknowledged to be dynamic, as preferences may vary over time, as new or improved climate information becomes available or technologies emerge or evolve. This being so, robust approaches that consider flexibility and the time dimension can be very valuable in supporting decision-making under uncertainty (Chambwera et al., 2014).

From a methodological perspective, a robust analysis can be defined based on three components (Markandya, 2014). The first consists of assessing robustness: measures are defined as robust when they are effective in a wide range of future scenarios. Typically, low- and no-regret measures provide robustness in situations of uncertainty about the future. However, some measures capable of coping with a wide variety of scenarios may prove too costly; others, such as early warning systems, are cheaper but will not suffice to cope with some extreme situations, e.g. 500-year return-period floods, and are not likely to prevent all damage in the event of any flood. The second component relates to flexibility in decision making. In this case, low- and no-regret options could be decided upon in the short term, and one could then wait for more and better information or technologies before implementing costlier policies. Finally, the third component analyses the adaptability of options in response to future information or needs. For example, building a dyke with foundations strong enough to support a 2 m-high wall that could be built in the future.

There is an extensive scientific literature about assessing and modelling catastrophic flood risks. A good starting point may be Walker (1997), who analyses the development of catastrophe modelling and explains some of the potential uses of the output of these models. Grossi and Kunreuther (2005) examine how catastrophe models can be used for assessing and managing the risks of extreme events, and Grossi and Zoback (2009) review the evolution of catastrophe models, since the first generation exclusively oriented to insurance companies, to current integrated models and provides a few examples of their application. The IPCC (2012) has also published a special report on the challenges of disaster and extreme event risk management in a context of high decision-making uncertainty with the aim advancing in climate change adaptation. Finally, Amendola et al. (2012) is a good reference to understand current challenges and the methodological complexities of disaster risk management and related decision making, based on integrated assessment models developed at IIASA.[1]

In this study, we use a stochastic model with several risk factors: the frequency of extreme events— modelled with three Poisson processes— and a stochastic extreme events growth rate for damage due to climate effects and socio-economic effects under uncertainty. We then consider three approaches to incorporate uncertainty into decision-making in relation to adaptation to climate change: the first one consists of calculating the net present value of expected damage over time using the stochastic model, considering that extreme events will increase in the future due to climate and socio-economic conditions. Here an analytical solution for the Net Present Value of investment at a given time is estimated.

The second approach is based on estimating risk measures. Risk measures play an important role in situations of uncertainty and are widely used in the field of finance with respect to the probability of rare, adverse events. There are two main risk measurements: Value-at-Risk (VaR) and Expected Shortfall (ES). VaR(α) at confidence level α is the value at which the probability of obtaining higher values is $1\text{-}\alpha$. That is, VaR (95%) represents the cost at which 5% of cases will give higher values. The second risk measure - the ES - is the expected damage when VaR is exceeded. That is ES(95%) represents the average cost of that 5% of worst cases. Value at Risk is a more standard measurement and is widely recognised by international financial regulatory bodies but ES is a better measure of risk for low-probability and high-damage events, as well as a more robust indicator for assessing risk (Rockafellar and Uryasev, 2002). In our case study, we estimate both measures of risk. These measures can also be used to define acceptable levels of risk together with stakeholders and policymakers (Abadie et al., 2017).

The third approach relates to the use of Real Options Analysis (ROA). ROA has been developed in the field of financial economics and is meant to deal with future uncertainties in a project's implementation (Zeng and Zhang, 2011). A real option itself, is the right — but not the obligation — to undertake certain business initiatives, such as deferring, abandoning, expanding, staging, switching or contracting a capital investment project (Trigeorgis, 1996). In the context of adaptation economics, it can be said that “ROA quantifies the investment risk with uncertain future outcomes” (Watkiss et al., 2015: 407), which is very useful when considering the value of flexibility of investments. “This includes the flexibility over the timing of the capital investment, but also the flexibility to adjust the investment as it progresses over time, i.e. allowing a project to adapt, expand or scale-back in response to unfolding events. The approach can therefore assess whether it is better to invest now or to wait – or whether it is better to invest in options that offer greater flexibility in the future.” (Watkiss and Hunt, 2013: 2).

This investment analysis tool has been widely used in the energy sector (e.g. Abadie et al., 2014) but it has recently sparked considerable interest in the field of adaptation economics as it “aligns with the concepts of iterative adaptive (risk) management, providing a means to undertake economic appraisal of future option values the value of information and learning, and the value of flexibility, under conditions of uncertainty. It can therefore justify options (or decisions) that would not be taken forward under a conventional economic analysis” (Watkiss and Hunt, 2013: 2).

Relatively few applications of ROA exist for adaptation alternatives or investment projects. One exception is Kontogianni et al. (2014) where alternatives for protecting the Greek coast from sea-level rise are analysed. The authors conclude that the analysis “through recognizing the uncertainty and keeping all the options open till uncertainty is resolved, provides an adaptation strategy that may be beneficial […] for the society” (Kontogianni et al., 2014: 74). Another interesting example can be found in Jeuland and Whittington (2013), with an application to water resource planning in Ethiopia for the construction of several large dams and an operating strategy accounting for uncertainties due to climate change. A third example is the paper by Woodward et al. (2011) on flood risk management in the Thames Estuary. The authors conclude that “the results obtained demonstrate the

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