European Journal of Operational Research 253 (2016) 856–868

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Interfaces with Other Disciplines

It's not now or never: Implications of investment timing and risk aversion on climate adaptation to extreme events[☆]

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ARTICLE INFO

Article history:
Received 21 January 2015
Accepted 22 January 2016
Available online 28 January 2016

Keywords:
Climate change adaptation
Investment timing
Catastrophic risk
Risk aversion
Real option

ABSTRACT

Public investment into risk reduction infrastructure plays an important role in facilitating adaptation to climate impacted hazards and natural disasters. In this paper, we provide an economic framework to incorporate investment timing and insurance market risk preferences when evaluating projects related to reducing climate impacted risks. The model is applied to a case study of bushfire risk management. We find that optimal timing of the investment may increase the net present value (NPV) of an adaptation project for various levels of risk aversion. Assuming risk neutrality, while the market is risk averse, is found to result in an unnecessary delay of the investment into risk reduction projects. The optimal waiting time is shorter when the insurance market is more risk averse or when a more serious scenario for climatic change is assumed. A higher investment cost or a higher discount rate will increase the optimal waiting time. We also find that a stochastic discount rate results in higher NPVs of the project than a discount rate that is assumed fixed at the long run average level.

1. Introduction

A major concern with global warming is that the climate system may become more energetic and the frequency and severity of catastrophic events will increase in the years to come. The rising number of natural disasters during the last two decades has put governments under increasing pressure to implement policies and investment projects to facilitate climate change mitigation and adaptation (Hochrainer-Stigler, Mechler, Pflug, & Williges, 2014; Van Aalst, 2006). Mitigation requires time to yield impacts, since greenhouse gases have a long life and the global climate system takes time to cool down once being heated. Therefore, it is generally assumed that the global temperature is going to increase before stabilizing, even if emissions are substantially reduced (Solomon, 2007). Therefore, the risks related to catastrophic events are expected to increase regardless of existing and potential additional mitigation efforts, making climate adaptation an essential task.

Australia is well-known for bushfire, storm surge and flood disasters. Several studies suggested that these events would become more frequent in many regions of Australia and more attention should be paid to adaptation measures (Antón, Cattaneo, Kimura, & Lankoski, 2013; Garnaut, 2011; Murphy & Timbal, 2008). Climate adaptation requires input from all levels of government and could be one of the most challenging tasks in environmental management. While it has often been argued that action is most effective at the local level, local government is confronted with the complex and difficult task of planning and implementing mitigation and adaptation actions within existing budget constraints. This requires an economic framework to evaluate potential climate adaptation options to facilitate decision making.

Although climate adaptation is required for many sectors and in many cases involves expensive investments, see e.g., Felgenhauer and Webster (2013), there are a few empirical studies conducting cost benefit analysis for catastrophic risk reduction projects. In Appendix A we provide an overview over recent studies that evaluate catastrophic risk reduction projects. These include the work of Kirshen, Knee, and Ruth (2008); Michael (2007); Tsvetanov and Shah (2013), and West, Small, and Dowlatabadi (2001) who examine storm surge risk in coastal areas as well as studies by Bouwer, Bubeck, and Aerts (2010); Brouwer and van Ek (2004); Mathew, Trück, and Henderson-Sellers (2012), and Zhu, Lund, Jenkins, Marques, and Ritzema (2007) who examine flood risk in riverine regions. In these studies, except for West et al. (2001) and Michael (2007), it is assumed that the benefits of a risk reduction project

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[☆] We would like to thank Professor Robert Mendelsohn, Professor Richard Tol and other participants of EAERE FEEM VIU European Summer School for their comments on a previous version of this paper. Our special thanks to the reviewers for their valuable comments and suggestions.

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http://dx.doi.org/10.1016/j.ejor.2016.01.044
0377-2217/

are equal to the expected avoided losses. This assumption holds when the potential losses are insured and the insurance premium is actuarially fair. However, in practice, it is often found that insurance premiums in laissez-faire markets may not be actuarially fair, especially for extreme events. Insurers may charge higher premiums when the risk cannot be accurately estimated, for example due to the uncertain impacts of climate change, to reduce their insolvency risk, or when risks are highly correlated (Ermoliev, Ermolieva, MacDonald, Norkin, & Amendola, 2000). Correlated risks require additional capital for insurers to protect themselves against large losses. Further, when spatially correlated losses occur, they may drain the capital of the insurance industry and put insurance firms under financial distress. Insurers may therefore require an additional premium to bear the risk of financial distress (Cummins & Trainar, 2009; Froot, 2007). Furthermore, assuming risk neutrality when evaluating adaptation projects is likely to result in an underestimation of the project benefits and a low level of public investment in risk reduction infrastructure. We also find in this study that assuming risk neutrality may lead to unnecessary investment delay for risk reduction projects.

West et al. (2001) provide one of the first studies to estimate the cost of increased storm surge damage under climate change based on insurance premiums. In their model, the distance of a property from the shoreline determines the expected damage to a property and the insurance premium. Under climate change, sea level rise reduces the distance to the shoreline of all properties in a coastal region and increases the insurance premiums accordingly. The cost of increased damage is found by aggregating additional discounted premiums required in future years. Michael (2007) follows a similar approach, but uses the elevation of a house instead of its distance to the shoreline to determine the insurance premium. In both of these studies, insurance premiums are determined based on the assumption that the frequency and intensity of storms do not change in future years. This is a strong and possibly unrealistic assumption since it is often argued that a warmer climate in future periods will result in more frequent and more severe catastrophes (Parry, Canziani, Palutikof, Van der Linden, & Hanson, 2007). The method proposed in this paper does not require such an assumption.

In addition to the risk neutrality assumption, most studies – with the exception of West et al. (2001); Zhu et al. (2007) and Tsvetanov and Shah (2013) – use the NPV rule to determine the investment decision, i.e., a project is invested if its NPV is positive. However, investing immediately based on a positive NPV may not be optimal if investing at a future time provides an even higher NPV. This occurs when the NPV of the project is increasing in investment time, see, e.g., Firoozi and Merrifield (2003) and Hagspiel, Huisman, and Nunes (2015), what may often be the case for projects that deal with risk reduction of climate impacted hazards. Annual benefits of such a project typically increase over time due to increasing catastrophic risk or growing potential losses, while annual costs such as interest expenses on the investment cost or project maintenance costs remain rather constant. Therefore, deferring instantaneous investment to a future period may help to avoid the initial years' negative impact on the NPV, when annual benefits of the project are lower than the occurred costs. Overall, in such a situation, a deferral of the investment would be expected to increase the NPV of the project. Therefore, in order to obtain the optimal investment decision, one also needs to determine the investment time that yields the highest NPV for a project.

West et al. (2001), Zhu et al. (2007) and Tsvetanov and Shah (2013) departed from the NPV rule to examine the optimal time to invest. In Zhu et al. (2007), water inflows are simulated from historical data or climate models and used in a hydraulic model to generate losses. In contrast, West et al. (2001) derive the expected avoided losses using a statistic model called the Loss Distribution Approach (LDA).[1] The simulation approach used in Zhu et al. (2007) is computationally intensive, in particular due to the time required to run complex climate models. The LDA, on the other hand, is tractable and can give rise to an analytical solution to the investment problem. In practice, the two approaches can be combined, with simulation results being used to estimate the parameters of the LDA, as suggested in our approach. Tsvetanov and Shah (2013) use the damage curve approach that relates the total loss in each period with the corresponding return period.[2] The damage curve is then used to estimate the expected loss and an optimal adaptation time is selected to maximize the net present value of a project.

In this paper, we propose a general economic framework to determine optimal adaptation decisions at the local level. Different from previous studies, we evaluate the investment benefits based on optimal timing of the investment as well as the risk preference of the representative agent in the insurance market. In our model, risk preference is represented by a parameter that is separated from the loss distributions. As such, the framework allows loss frequency and severity distributions to adjust as the climate changes. A future climate that entails more frequent catastrophes or more heavy tailed severity distributions will result in a larger insurance premium in our model. In contrast, the framework in West et al. (2001) and Michael (2007) utilizes insurance premiums specified for different elevations under current climate conditions only. As a consequence, the impact of changes in the loss frequency and severity distribution on insurance premiums cannot be determined and incorporated (unless risk neutrality is assumed). Another advantage of our model is that different heavy tailed distributions can be used to model loss severity, which allows to incorporate the impact of not only the mean but also the tail characteristics of extreme losses on insurance premiums and investment project values.

Our model is developed in a semi-continuous time framework and provides a simple formula to determine the optimal time for adaptation investment. Using a case study of bushfire risk management, we illustrate that investing at the optimal time has the potential to significantly increase the net present value (NPV) of a project, even though the project provides a positive NPV if invested immediately. Risk preference also has an important impact on the NPV of the project, but tends to be less important in comparison to the impact of investment timing. Factors that significantly influence investment decisions and outcomes include climatic change scenarios, risk preferences, investment costs and the applied discount rate. We find that a more serious scenario of climate change and higher risk aversion increase the NPV of a project for any investment time and will reduce the optimal waiting time. This is consistent with the precautionary principle, which encourages early action to protect the environment when there is potential for serious or irreversible damage (UNEP, 1992). A precautionary decision maker will most likely base her decision on an extreme, serious climate change scenario and invest in the project early. The value added by the investment model compared to a simple NPV rule, i.e. invest immediately if the project provides a positive NPV, is found to be lowered in these cases. In contrast, higher investment costs and higher discount rates increase the optimal waiting time and raise the value added by the investment model. We also illustrate that allowing the discount rate to vary stochastically,

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[1] The Loss Distribution Approach is a term commonly used in insurance analysis, see e.g. Klugman, Panjer, and Willmot (2008) and Shevchenko and Wüthrich (2006). In this paper, it is used to refer to catastrophic risk modeling.

[2] The return period indicates how frequent an event is. As such, a return period indicates the probability that the event occurs.