



On analytical models of optimal mixture of mitigation and adaptation investmentst[☆]

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ARTICLE INFO

Article history:

Received 4 September 2017

Received in revised form

16 January 2018

Accepted 9 March 2018

Available online 13 March 2018

Keywords:

Mitigation

Adaptation

Cost-benefit analysis

Optimal investment

Development level

ABSTRACT

Determining the optimal combination of mitigation and adaptation investments is an important topic in policy making to combat climate change. Some analytical results on the relationship between the optimal ratio of adaptation to mitigation and development level have been reported in the literature. In this article, we examine this relationship in greater detail using a simple model with general return functional forms and analytically show that the relationship can take various forms. The results suggest a desirable design of empirical studies on adaptation measures. In addition, the insights obtained in the simple model are useful to understand more complicated models.

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1. Introduction

Adaptation, the importance of which was recognized later than that of mitigation, has acquired a prominent place in policy making on climate change. A possible reason for the rising attention to adaptation is that people are more aware of that climate change damage cannot be altogether avoided or that international cooperation for combating climate change is difficult (Tol, 2005). The Conference of the Parties 21st Session to the UN Convention on Climate Change (COP21), which was held in 2015, recognized an increasing role for adaptation and emphasizes the benefits of cost reductions for adaptation efforts. New York City's Flexible Adaptation Pathways and the Climate Smart Adaptation of the Queensland Climate Change Centre of Excellence are famous examples of adaptation efforts at the regional level.

The growing attention on the topic has demanded studies on

various topics concerning adaptation. Though we do not intend to be exhaustive here, the literature includes a number of case studies that have been accumulated and have clarified feasibility of adaptation options, costs and benefits of each option, and practical issues in implementation (see, for example, Berrang-Ford et al., 2015). Other works analyze the implication of adaptation to the sustainability of international cooperation (Zehaie, 2009; Ebert and Welsch, 2012; Heuson et al., 2015). de Bruin et al. (2009) and de Bruin (2011) add an adaptation decision to the DICE model, which is an Integrated Assessment Model (IAM), and examined how adaptation interacts with mitigation decisions in balancing between developing climate change strategies and maintaining healthy economic activities. Barrage (2015) focus on the fiscal revenue effects of mitigation and adaptation options and discuss implications in the context of optimal taxation.

Adaptation aims to reduce the vulnerability of social systems and offset the effects of climate change. Compared to mitigation, adaptation is conducted at geographically and politically smaller scale (Buob and Stephan, 2011). The advantage and disadvantage of adaptation to mitigation arise from this feature. The advantage is that adaptation in each region can independently provide benefits private to regional societies and thus the free-riding is less problematic. The disadvantage is the difficulty in monitoring adaptation activities. The variety and case-specificity of adaptation activities require a lot of efforts for comprehensive evaluations (Tol et al.,

[☆] This research was supported by the Environment Research and Technology Development Fund (S-14) of the Ministry of the Environment, Japan, and Specially Promoted Research through a Grant-in-Aid (Scientific Research 26000001) from the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT).

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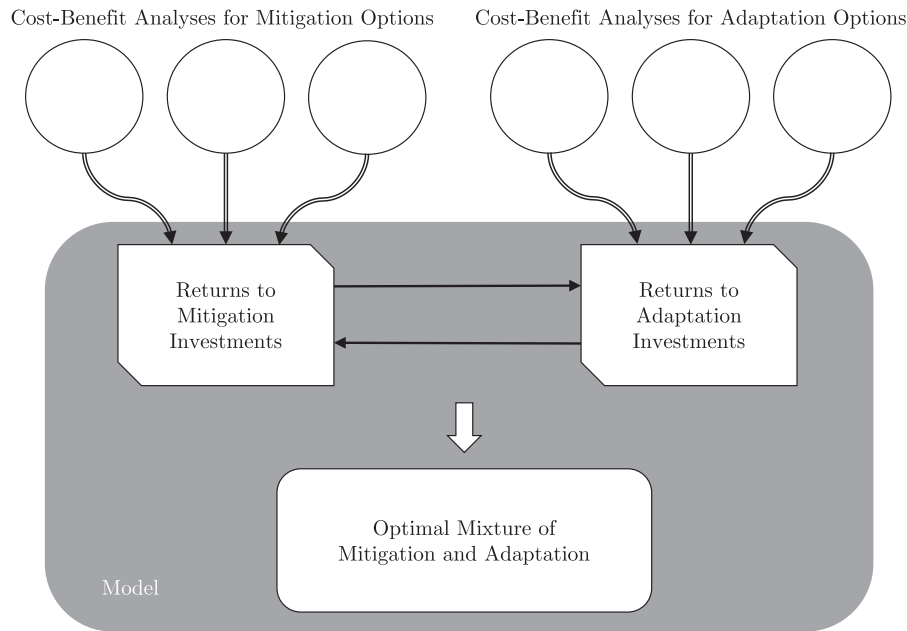


Fig. 1. Research framework.

1998).

Previous works in the literature have been working on how to allocate limited resources between mitigation and adaptation investments. This work aims to contribute to the literature by examining the allocation problem, drawing a unified understanding of previous results in the literature, and suggesting a design of empirical works for achieving a more socially desirable mixture of mitigation and adaptation investments. Fig. 1 describes the framework of our research. The shaded area indicates the model of mitigation and adaptation investments that we analyze. We analytically examine how properties of returns to mitigation and adaptations affect the optimal mixture of the two types of investments. This part is depicted by the white arrow at the center of the shaded area in the figure. Based on the results of the analysis, we make suggestions about a desirable design of cost-benefit analyses of mitigation and adaptation options, which are the source of empirical evidence about returns to mitigation and adaptation investments.

In this article, we examine the relationship between the optimal ratio of adaptation investment to mitigation investment, which has been analyzed in the literature, in greater detail. First, we formulate a simple static model of mitigation and adaptation investments with general return functional forms in Section 2. The model includes a parameter capturing the amount of available resources for mitigation and adaptation, which we interpret as the level of development. The objective function is assumed to take a multiplicative form to capture the feature of the mitigation-adaptation investment problem whereby an increase in a given mitigation measure decreases the necessity of adaptation, and vice versa. The multiplicative form can endogenously arise in some specific contexts, as we discuss in Section 4, and should be understood as a crude way to incorporate the feature into the model in other contexts.

Our model is very simple. For example, compared to the model in Bréchet et al. (2013), our model is abstracted from dynamics, stock nature of pollution, and economic production activities. Relative to Ingham et al. (2013), ours does not take strategic interaction among countries or uncertainty into account. Compared to Zemel (2015), our model does not consider dynamics, stock

nature of pollution, and uncertainty. These comparisons are summarized in Table 1. The advantage of the simplicity is the high tractability of the model, which allows us to analyze the relationship more intensively than what has been done in the literature. In addition, as we discuss below, insights from our model are applicable to those more structured models.

Our main result is reported in Section 3. After showing that an equation determines the optimal ratio, using the equation, we analytically prove that the relationship can exhibit various patterns: any function in a wide class can yield the optimal ratio if we appropriately select a pair of return functions. Note that all functional forms for mitigation and adaptation returns that are included in the class satisfy reasonable assumptions, in that they are monotonic and have diminishing marginal returns. To demonstrate the breadth of the range of potential functions, we present several examples. The examples demonstrate that the optimal ratio can be (i) constant, (ii) monotonically increasing, (iii) monotonically decreasing, (iv) U-shape, (v) Inversed U-shape, or (vi) more complicated patterns.

Although our model is static and extremely simple, the insight from the examples is useful to understand more complicated models, such as that of Bréchet et al. (2013). In Section 4, we show the optimal ratio in the model of Bréchet et al. (2013) is determined by an equation similar to that in our simple model. Then, we provide examples in which various patterns that are similar to the examples in our model arise. We also relate our result to Zemel (2015). In his model, the multiplicative form arises endogenously and, therefore, offers an interpretation of the multiplicative form of utility functions. We show that the optimal ratio is characterized similarly in Zemel (2015).

In Section 5, we discuss qualitative features of the return functions and relate them to empirical evidence. Cost-benefit analyses provide information about returns from adaptation investments and constrain qualitative features of the adaptation return function.¹ We also discuss the relationship between our result and the

¹ See ECONADAPT (2015) and Watkiss (2015) for a review of cost-benefit analyses for adaptation projects.

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