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CLIMATE POLICY DECISIONS UNDER AMBIGUITY AND PRESSURE OF TIME

By **Yu-Fu Chen*, Michael Funke† and Nicole Glanemann‡**

This article summarises our studies on the optimal timing of climate policy adoption by focusing on ambiguity in the climate damage cost assessments (Chen et al., 2011) and on the limited time to achieve certain climate policy targets (Chen et al., 2012). Using real options theory, both studies conclude that climate policy adoption should be accelerated. However, the implementation of climate policy is evaded by high uncertainty about critical parameters and possible climate pathways.

Keywords: Climate policy, CO2 scenarios, Knightian uncertainty, k-ambiguity, real options, non-perpetual real options

JEL Classification: C61, D81, Q51, Q54

1. Introduction

The future dynamics of greenhouse gas emissions, and their implications for global climate conditions in the future, will be shaped by the way in which policy makers derive mitigation decisions based on climate projections that involve ubiquitous uncertainty. Therefore, meaningful policy recommendations require a thorough understanding of the optimal climate policy decision under uncertainty.

The studies we briefly report here aim to contribute to a better understanding of the optimal timing to cut emissions by drawing attention to (i) the lack of knowledge of how future climate damage costs will evolve (Chen et al., 2011) and (ii) the limited time to achieve certain climate targets like the 2°C target (Chen et al., 2012). *[Note 1]*

A considerable lack of scientific understanding and uncertainty about future economic development leads to enormous ambiguity in the impact assessments of climate change (e.g., Stern, 2007). Apart from different appraisals of countries' vulnerabilities, impacts of extreme weather events and catastrophes are often neglected. Moreover, underlying assumptions about future societies' capability to adapt are highly controversial. The lack of knowledge implies that it is impossible to assign specific probabilities to all imaginable outcomes. In economic theory, this kind of uncertainty is conceptualised by Knightian uncertainty (Knight, 1921) and is referred to as ambiguity, whereas the concept of known probabilities is called risk. Examining how people react to situations of these different notions of uncertainty, experiments give evidence that people usually prefer situations where probabilities are known (Ellsberg, 1961). Accordingly, decision makers are usually assumed to be prone to ambiguity aversion, which is shown to lead to a behavioral bias towards extreme pessimism (Gilboa and Schmeidler, 1989). Recently, the Knightian uncertainty concept has been transferred to analyse the environmental policy decision (Asano, 2010; Vardas and Xepapadeas, 2010). These studies come to the same conclusion that the policy has to be adopted earlier than in a situation of risk. Hence, this approach can be considered to be a formal way to model the precautionary principle. We re-examine this conclusion by investigating the ambiguous assessments of climate damage costs and aim to clarify the importance of ambiguity for the timing of when to reduce emissions.

The other study focuses on climate policy targets such as the 2°C target, which limits global warming to 2°C throughout the twenty-first century. This target has become a critical part in emission reduction

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negotiations and the European Union has committed itself to this target by aiming to cut its emissions to 80 percent below 1990 levels by 2050.2 However, recent studies indicate that the 2°C target will move out of reach, unless global emissions are significantly reduced in the next few years (e.g., IEA, 2011; Meinshausen et al., 2009). We thus investigate whether this closing window of opportunity accelerates climate policy adoption.

2. Modelling Framework

The decision of when to adopt climate policy needs to take into account that (i) there is uncertainty of the future benefits of climate policies, (ii) waiting allows policy makers to gather new information on the uncertain future, (iii) the required investments are at least partially irreversible, which means that disinvesting cannot fully recover the previously made expenditures, and (iv) the greenhouse gases accumulate and remain in the atmosphere long after they are emitted. On the one hand, the opportunity to wait for new information to arrive may induce the policy maker to delay costly and irreversible policy measures. On the other hand, waiting causes a continuing global warming trend and future climate damage costs of unknown size. Hence, it seems rational to cut emissions as soon as possible. These considerations show that the interaction of irreversibility and uncertainty is important for the timing of climate policy adoption and more analysis is required to understand these opposing irreversibility effects.

The value of delaying investments – also referred to as the value of managerial flexibility (e.g., Sick, 1995) – is considered to be a real option by economic theory. The idea is to perceive the opportunity to adopt a climate policy as a financial call option. On financial markets the investor pays a premium price to get the right to buy an asset for some time at a predetermined price that is eventually lower than the spot market price of the asset. In this analogy, the policy maker, through the climate policy decision, pays a price which gives her the right to use a mitigation strategy, in return for lower future damage costs. Both studies expand the modelling framework by Pindyck (2010, 2012) on uncertain outcomes and climate policy. To reflect ambiguity in climate damage cost assessments, a real options approach by Nishimura and Ozaki (2007) is utilised, which is designed to analyse the interplay of irreversibility and Knightian uncertainty. In the other study, the idea of modelling the limited time to act is to restrict the temporal availability of the real option to mitigate. After the option has expired, the climate target moves out of reach and the economy has to bear the consequences by the high-emission scenario. Although this set-up is very stylised, because aiming for a different and less strict target would make another real option available, it still allows us to answer whether such a deadline accelerates climate policy adoption.

3. Results

The problem we must solve is referred to as ‘optimal stopping’. The idea is that the decision about whether to adopt climate policy has to be reassessed as soon as new information about the uncertain processes pours in and enriches the current state of knowledge. In this case, the benefit of mitigation is compared with the expected value of waiting. The optimal strategy is to stop and reduce emissions right now if the benefit of mitigation is greater than the value of waiting and to continue waiting otherwise. In the numerical simulations of our studies, the optimal strategy is illustrated by a threshold curve that separates the area of inaction (below the curve) from the area of action (above the curve). The threshold is derived in terms of X that describes the observed value of the sensitivity of GDP losses to global warming. The most important goal of these simulations is to see how certain crucial aspects of the model react to changes in parameters.

In Chen et al. (2011) the degree of

ambiguity is depicted by the parameter k. Figure 1 shows the impact of k for three different calibrations of the trend α in X. The solutions for $k=0$ characterise the situation of risk, in which the probabilities are known with certainty. The numerical simulation indicates an acceleration of climate policy for higher degrees of Knightian uncertainty, i.e. increasing ambiguity has an unequivocally positive impact upon the timing of optimal climate policy and shrinks the continuation region where exercising climate policy is suboptimal. Hence, this result agrees with the above-mentioned findings by Asano (2010) and Vardas and Xepapadeas (2010). Furthermore, Figure 1 demonstrates that this result is insensitive to the choice of α, which can be interpreted as a measure of the economy's vulnerability. The higher α is, the more vulnerable the economy over time. Therefore, it is clear that a higher vulnerability implies a decrease of the threshold.

Additional observations concerning the scale of the ambiguity effect emerge from Figure 2, which provides a comparison with the effects caused by other parameters. The graphs in Figure 2a – 2c relate to the sensitivity of the policy decision to the discount rate of future benefits and costs, the mitigation costs and the projected temperature increase in the business as usual scenario, respectively. These parameters play a crucial role in economic research, because their correct calibration is controversially discussed. Therefore it is of utmost importance to investigate how the results change for alternative assumptions of these parameter values. All three graphs confirm that Knightian uncertainty accelerates mitigation efforts, but the simulations also show that marginal changes in these parameters exert a more pivotal influence on the threshold than a marginal change of the degree of ambiguity. Put differently, the precautionary principle is not an all-dominating factor in the policy decision.

Based on Chen et al. (2012), Figure 3 offers an isolated inspection of how alternative time horizons after which the climate policy target moves out of reach affect the threshold of taking action. Broadly speaking, the result suggests that the restricted availability of the real option to mitigate has a significant impact on the threshold, in particular if the window of opportunity closes soon. This result elevates the urgency of climate policy adoption. Figure 4 tests the robustness of this result by exemplifying the effects of other parameters. The numerical simulations and the results resemble those described above.

As demonstrated by Figure 4a, the decision when to implement climate policy is radically influenced by the projection of the temperature increase. The expectation of a very high temperature increase accelerates mitigation efforts much faster. Similarly, Figure 4b shows that an increase of the discount rate bolsters the reasons for taking a 'wait and see' attitude and even swamps the acceleration by the limited time to act. Hence, even the limited time to act appears to be of minor importance to the policy decision. In other words, the closing window of opportunity probably exerts too weak an effect to entirely change the reluctant attitude towards climate policy.

4. Conclusion

Our studies aim to contribute to a better understanding of the optimal timing of a climate policy adoption by drawing attention to (i) the lack of knowledge of how future climate damage costs will evolve and (ii) the limited time to achieve certain climate targets like the 2°C target.

The economic literature shows that the interaction of irreversibility and uncertainty generates a value of delaying policy measures. Considerations of the optimal policy timing needs to take into account this value, which is described by the real option to mitigate. Accordingly, we develop a real options framework that models the lack of knowledge by Knightian uncertainty. In the other study, we incorporate the closing window of opportunity by making the option to reach the climate policy target only temporally available. The simulations show that Knightian uncertainty as well as the limited time to act accelerate climate policy adoption. However, their effects are comparatively small. Neither the lack of knowledge nor the urgency to act have an all-dominating influence on the policy maker's decision. Despite the urgency to act, a further delay of investments into a decarbonised economy can be expected.

Notes

[Note 1] We are indebted to the participants at the CESifo Area Conference on Energy and Climate Economics in Munich (October 2011), the Annual Conference of the Royal Economic Society (RES) in Cambridge (March 2012), the Conference on Sustainable Resource Use and Economic Dynamics (SURED) in Ascona (June 2012), the Annual Conference of the European Association of Environmental and Resource Economists (EAERE) in Prague (June 2012), the Annual Congress of the European Economic Association (EEA) in Malaga (August 2012) and the International Workshop on 'The Economics of Irreversible Choices' in Brescia (September 2012) for helpful comments on these studies. The research was supported through the Cluster of Excellence 'Integrated Climate System Analysis and Prediction' (CliSAP), University of Hamburg, funded through the German Science Foundation (DFG) and the International Max Planck Research School on Earth System Modelling (IMPRS-ESM).

[Note 2] For more information about the European Union's climate policy please see http://ec.europa.eu/clima/policies/roadmap/index_en.htm.

Figures

Figure 1. The Climate Policy Thresholds for Alternative Degrees of Ambiguity *k* and Trends *α* in the Sensitivity of GDP Losses to Global Warming

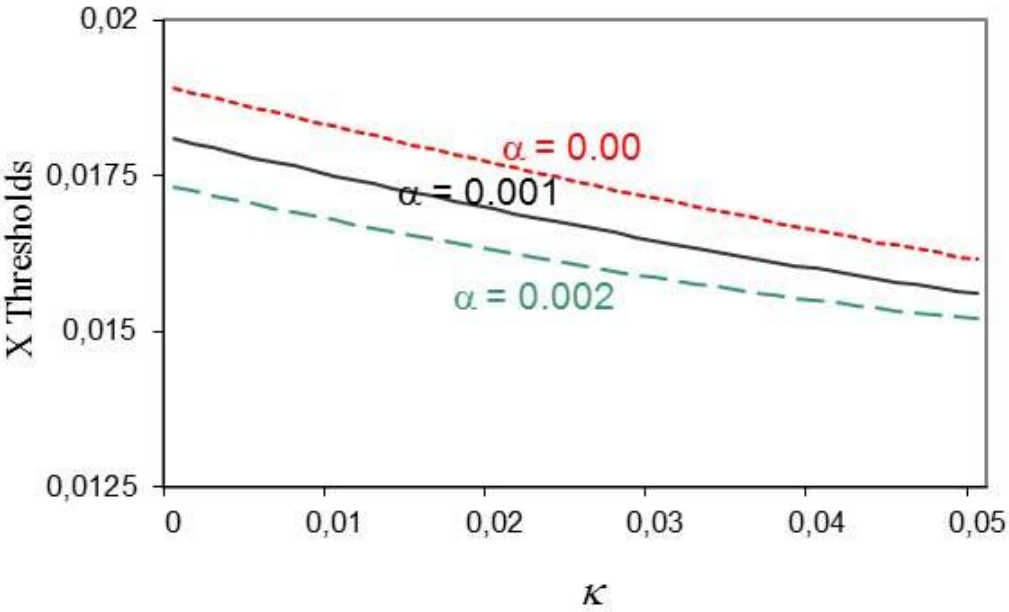
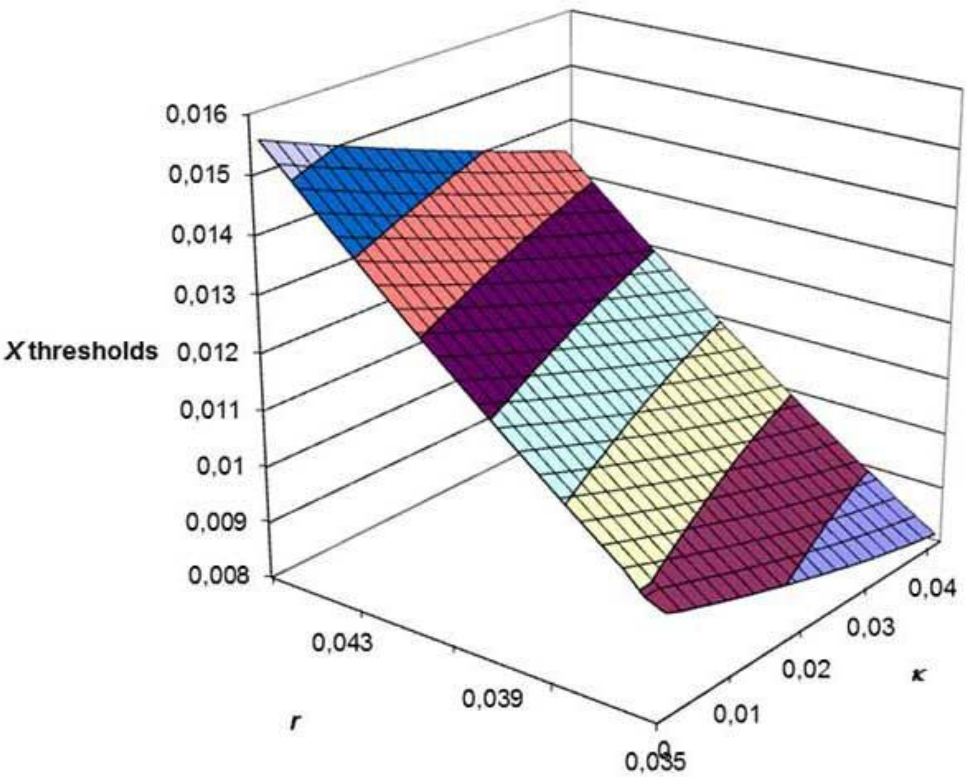
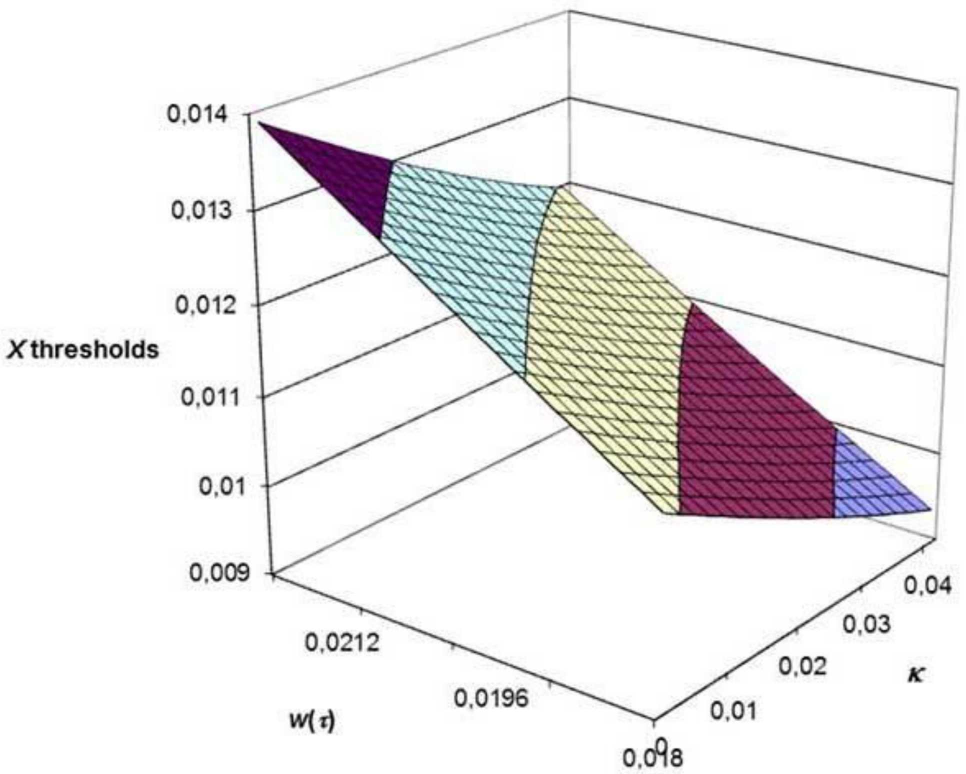


Figure 2. Sensitivity Analyses
(a) Sensitivity to the Degree of Ambiguity *k* and the Discount Rate *r* of Future Benefits and Costs



(b) Sensitivity to the Degree of Ambiguity *k* and the Mitigation Costs *ω(τ)*



(c) Sensitivity to the Degree of Ambiguity k and the Projected Temperature Increase *ΔTH* in the Business as Usual Scenario after hundred years

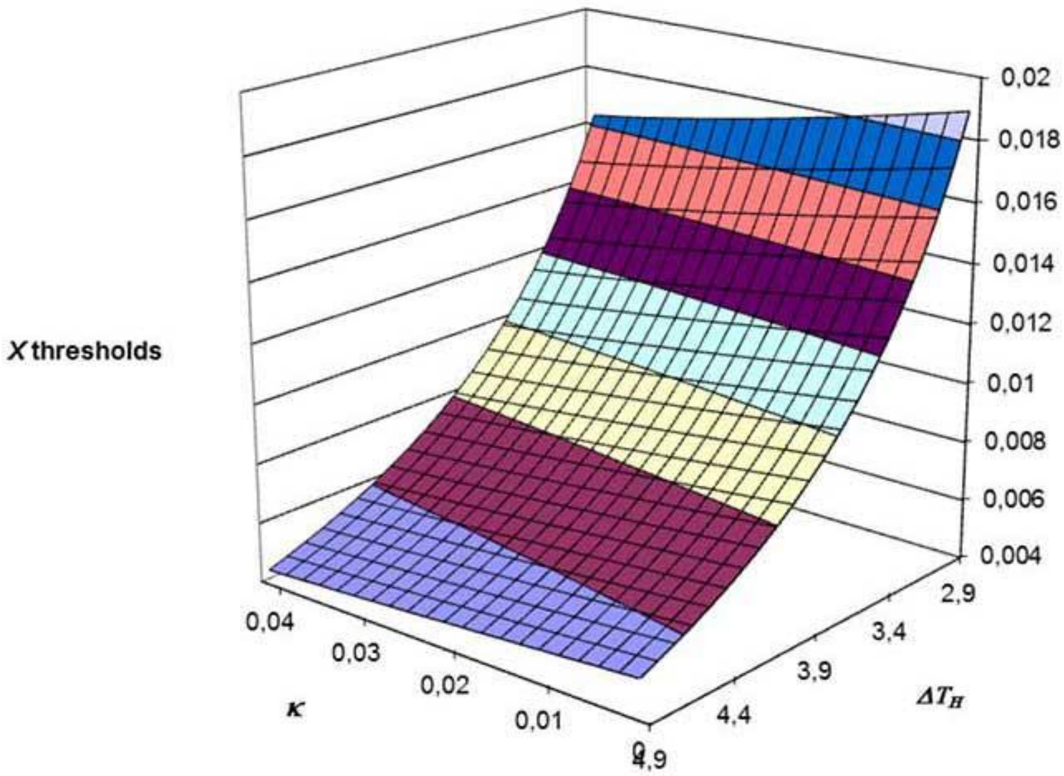


Figure 3: The Impact of Alternative Time Horizons *t on the Threshold**

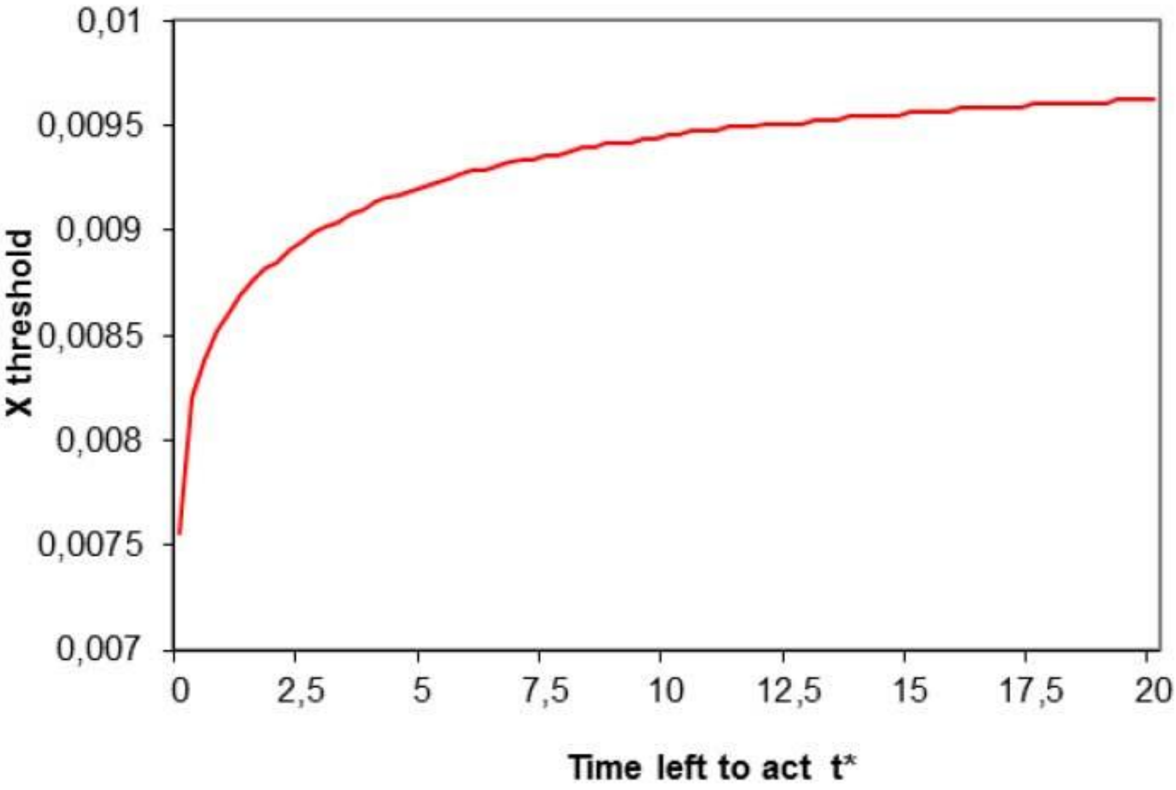
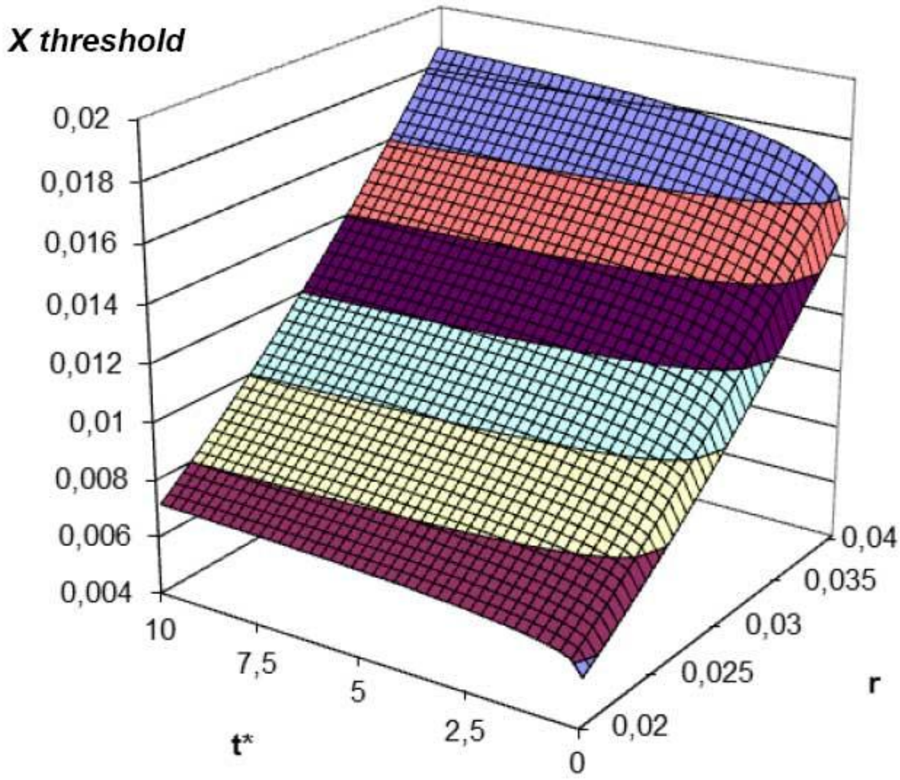
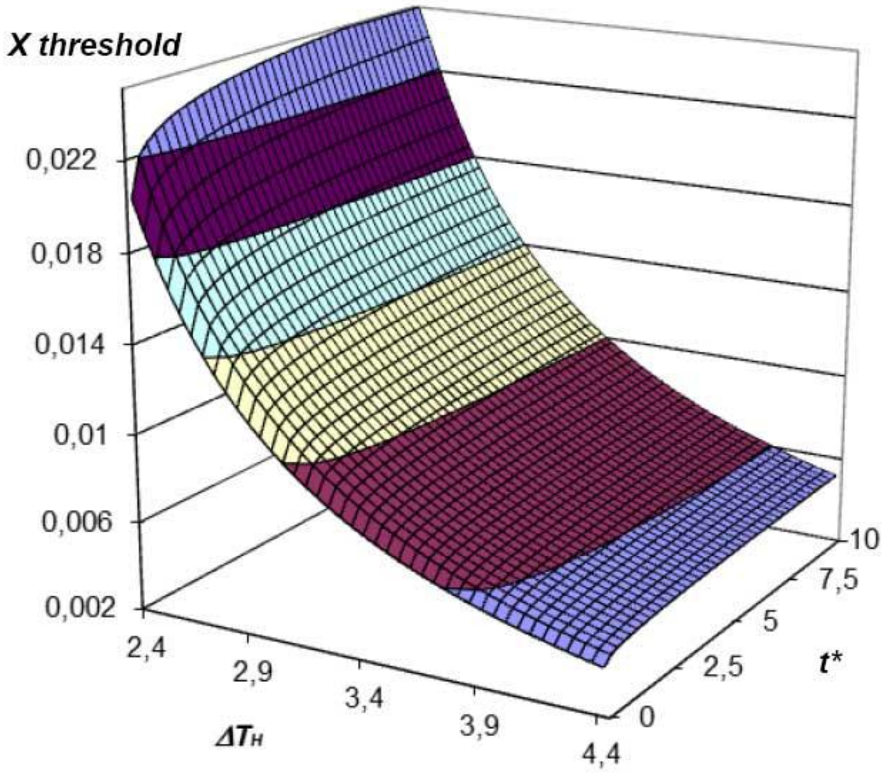


Figure 4. Sensitivity Analyses
(a) Sensitivity to the Residual Time *t to Meet the Climate Policy Target and the Discount Rate *r* of Future Benefits and Costs**



(b) Sensitivity to the Residual Time *t to Meet the Climate Policy Target and the Projected Temperature Increase *ΔTH* in the Business as Usual Scenario after Hundred Years**



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