Feedback-adjusted carbon prices[*]

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1 Background

Linear relationships are often assumed between economic variables, even when the actual relationships are not exactly linear. Linearly approximating a non-linear system, and hence ignoring possible feedback effects, may be a reasonable modeling strategy. If the current state is sufficiently close to a stationary point of the system, for example, the approximation error may be small enough and the feedback effects may not be of first-order importance. If the state is pushed away from the stationary point, however, linear models, no matter how well calibrated they may be, would fail to describe the behaviors of the underlying system.

A prominent example of a highly non-linear system is the Earth's climate, which is known to have numerous positive feedback mechanisms. Increasing anthropogenic carbon emission makes carbon sinks less effective and as a result a higher fraction of carbon will stay in the atmosphere. Recent results from Earth System Models indicate that the amount of heat absorbed by the deep ocean may drop significantly as temperature continues to rise (Tokarska et al., 2016). Since we have already been off the natural stationary state and are expected to move away from it further, any economic analysis involving the climate system should be subject to these feedback effects. In the literature of climate economics, however, the importance of climate-related feedback effects has received little attention so far. Linear climate models are still ubiquitous in economic analyses and are frequently used for deriving important policy recommendations.

2 Methods

I develop a theoretical framework to investigate, both qualitatively and quantitatively, how the optimal climate policy should be adjusted if the feedback effects in the climate system are properly taken into account. The framework allows for a wide range of non-linear feedback effects, including but not limited to the carbon and temperature feedbacks mentioned above. Figure 1 illustrates how the climate and the economy interact in this model. Allowing for feedback effects, and thus dropping the assumption of linearity, could easily compromise analytical tractability of otherwise tractable models. Nevertheless, I derive a closed-form expression for the social cost of carbon, or SCC, adjusted for these feedback effects. The feedback-adjusted SCC formula enables us to decompose the linear and non-linear effects on the optimal carbon pricing and thereby offers new analytical insights.

3 Results

I show that, relative to the benchmark linear model, the feedback effects increase the optimal carbon price way before those effects physically kick in. The carbon pricing formula does not

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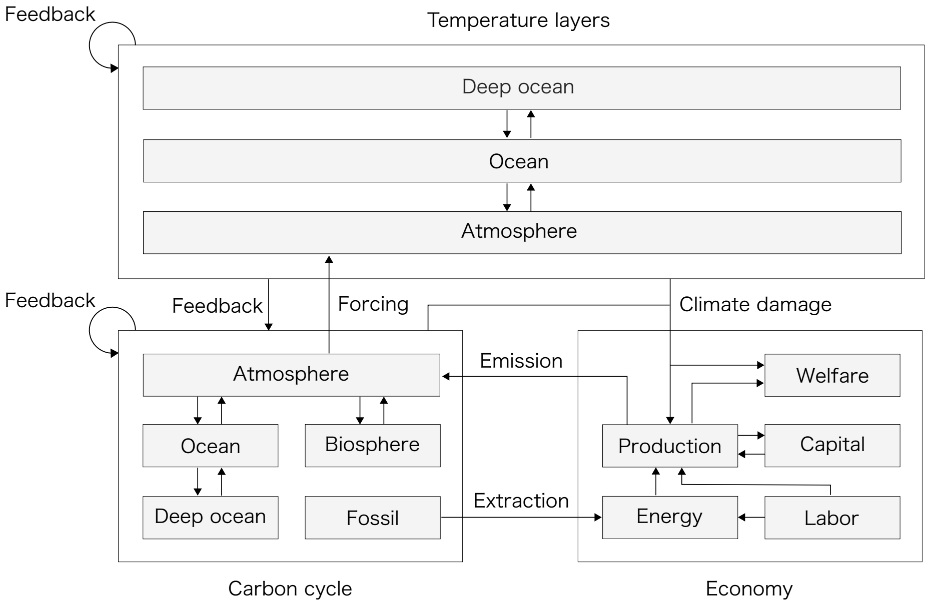

Figure 1: Structure of the model

only include the feedback effects we are facing under the current climate system, but it also reflects all possible feedbacks that could follow in the future. Even if the current climate system is still in good shape with no sign of malign feedbacks yet, the optimal carbon prices suggested by linear models are likely to be an underestimation. Moreover, unlike the linear model, the marginal utility damage of carbon emission is no longer constant, making the optimal carbon price properly sensitive to the current state of climate. Once the non-linear feedback effects are taken into account, therefore, any delay of carbon mitigation should imply more emission abatement in the future. This result is in stark contrast to the conventional wisdom in the literature where the cost of inaction only materializes in the form of suppressed welfare in the optimal path.

Including climate non-linearities in an analytical model also allows me to investigate the role of technological changes in a transparent manner. In the absence of non-linear channels, the production side of the economy, including technological changes, are largely irrelevant for carbon pricing because the optimal price is entirely determined by the constant marginal damage implied by the assumed linearity. Numerical models can incorporate both technological changes and non-linearities, but often fail to provide general insights. Based upon the feedback-equipped analytical model developed here, I derive an approximate closed-form expression for the optimal carbon price, properly adjusted for future technological changes. The SCC formula suggests that the expected decarbonization in the future lowers the carbon price today, but quantitatively the impact is likely to be insignificant.

References

Tokarska, K. B., N. P. Gillett, A. J. Weaver, V. K. Arora, and M. Eby (2016): "The climate response to five trillion tonnes of carbon," *Nature Climate Change*, 6, 851–855.