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Systems Innovation, Inertia and Pliability: A mathematical exploration with implications for climate change abatement

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Michael Grubb, Jean-Francois Mercure, Pablo Salas, Rutger-Jan Lange, Ida Sognnaes

Abstract This paper develops a stylised mathematical interpretation of innovation and inertia in economic systems, characteristics which feature in economics literature traceable back at least to Schumpeter and other economic theorists of innovation, as well as economic historians. Such characteristics are particularly important in energy systems and their potential response to climate change, where it is important to distinguish operational/fuel substitution from investment because the latter necessarily embodies both inertia and innovation, in systems as well as technologies.

We argue that integrated assessments of climate abatement need to focus on *investment*, including the associated characteristics of both learning and inertia, and derive in detail the mathematical basis for incorporating these factors through marginal investment cost curves. From this we also introduce the concept of 'pliability' as an expression of the ratio between costs which are significant but transitional (including learning investments, infrastructure and overcoming inertia), as compared to the enduring costs implied by purely exogenous technology assumptions.

We then incorporate these features in a global model of optimal climate mitigation and show that they can generate a very different profile and pattern of results from traditional 'integrated assessment' models, pinpointing the key sensitivities. We conclude that alongside all the attention devoted to evaluating climate change impacts and technology scenarios, far more effort should be devoted to understanding the structural characteristics of how the global energy system may respond to climate change mitigation.

Keywords Innovation, path dependence, inertia, learning by doing, climate change abatement, endogenous technological change, energy systems

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Contact m.grubb@ucl.ac.uk
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