International Max Planck Research School
on Earth System Modelling

Endogenous Technological Change in Strategies for Mitigating Climate Change

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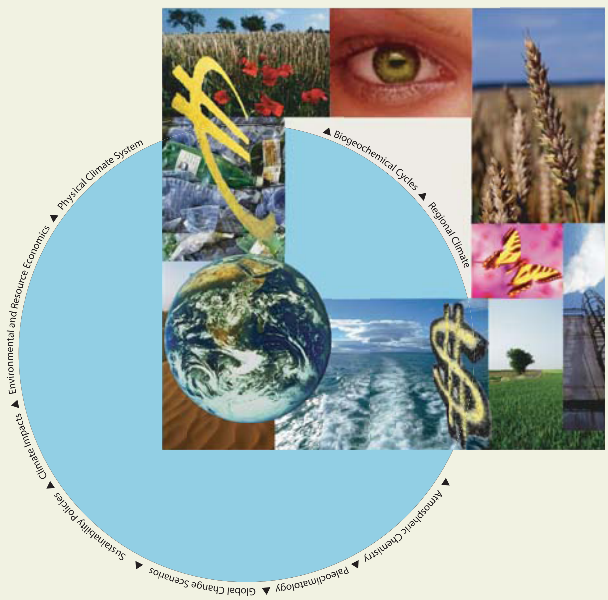

Summary

This thesis suggests that induced technological change has potential to reduce the burden that climate change mitigation puts on the economy. Furthermore, international cooperation on climate policy, which may trigger this induced technological change, may be achieved by linking climate negotiations to other issues. The starting point of the research presented here are the following two assumptions: first, action to mitigate climate change is necessary, and second, technologies will play a key role in this effort because technology and technological change facilitate the reduction of anthropogenic greenhouse gas emissions. As a consequence, the way technological change is described in integrated assessment models of climate change is of great importance, and a sound understanding of such endogenous technological change and its interaction with climate policies is needed.

There is empirical evidence that technological change is induced by policies. However, previous assessments of such induced technological change (ITC), i.e. technological progress triggered by policy, have been ambiguous about its responsiveness to climate policies and its potential to reduce the costs of mitigating climate change. On the other hand, a clear climate policy is required in order to induce the technological progress that might facilitate emission abatement at low costs. Ideally, climate policy ought to be global in order to prevent carbon leakage and to achieve efficiency. However, the literature on international environmental agreements suggest that the prospect for global climate policy is not bright. This raises two broad research questions: First, what is the role of ITC for climate change mitigation? And second, if there is a desirable contribution of ITC to mitigation, how can we achieve a global policy that triggers this technological change? The four papers presented in this thesis make contributions to these two questions.

The first paper focuses on the impact of ITC on the costs and strategies of mitigating climate change within a single integrated assessment model. I find that the impact of ITC is significant. The analysis reveals two “directions” of technological change. First, there is technological change that permeates the entire economy—this is reflected in a strong impact on the overall macro-economic costs of mitigation. Second, there is technological change whose impact is specific to the energy sector, as evident from strong changes in the composition of mitigation options. ITC therefore proves to be an influential determinant of mitigation costs and strategies. Costs may rise or fall due to ITC depending on whether progress in low carbon energy or progress in the resource sectors prevails. The effect of ITC on the competitiveness of mitigation options influences their contributions to overall mitigation. Moreover, this stresses the importance of models that resolve important technological options, including their potential of ITC, and account for the economy-wide impact of ITC.

The first paper used a single model with one specific formulation of ITC—but the question how to incorporate ITC in models is far from trivial. On the contrary, among models that include ITC there is a wide variety of approaches taken to describe ITC.

The second paper of this thesis compares ten state-of-the-art models that implement ITC. It explores the resulting differences in their assessment of ITC, identifies the underlying reasons for the differences, and draws conclusions that are robust across models. At the heart of this comparison are *ceteris paribus* scenarios that aim to isolate and expose the impact of ITC in the various models. The analysis reveals that ITC has potential to reduce costs, in many models substantially. However, the magnitude of the impact of ITC differs greatly among the models, ranging from 90 percent reduction of mitigation costs to almost no effect. Numerous reasons for this were identified, including business-as-usual emissions, differences in mitigation strategies, and modeling assumptions.

Business-as-usual emissions have a strong impact on mitigation costs because they determine the necessary emission reductions. Although an effort was made to harmonize the business-as-usual scenarios of the different models, considerable differences remained and need to be taken into account.

Mitigation strategies are explored on two levels of aggregation. First, abatement is decomposed into the contributions of reductions of economic output, energy intensity of output, and carbon intensity of energy. The analysis reveals that macro-economic models without explicit representation of the energy sector tend to focus their abatement strategy on reductions of energy intensity, whereas energy system models and models that feature an energy sector achieve the majority of their abatement through decarbonization. Decarbonization becomes particularly important for large reductions of emissions. Second, abating emissions through change in the composition of energy supply is considered. The composition of the energy supply mirrors the trends of the decomposition analysis. Models that focus their abatement strategy on reducing energy intensity and economic output are those that lack options to decarbonize the energy system, or that simply did not resolve the energy sector explicitly. Conversely, large reductions of carbon intensity are implemented through large shares of carbon free energy.

Three key modeling assumptions were identified that explain some of the major differences in model results: first, when models include additional market distortions, i.e. they describe a second-best world, climate policy may remove these distortions causing not costs but a benefit of climate policy. Second, the choice of the model type is influential because it often implies an equilibrium concept, which in turn implies different degrees of flexibility to react to climate policy. Third, different assumptions about foresight of economic agents determines their long-term investment behavior, which strongly influences mitigation strategies and costs.

The first two papers looked at climate policies implemented as global policy targets taking for granted that policies are agreed upon and implemented to achieve the targets, although this is known to be difficult. The remaining papers look at the potential of issue linking to help to build such agreements. To address issue linking, I develop a model of coalition formation, which incorporates international trade and sanctions as well as knowledge spillovers from research cooperation and international standards.

In the third paper, I show in numerical experiments that introducing trade sanctions positively affects international cooperation. Participation rises with the tariff rate, up to full cooperation. How quickly participation rises depends on the ease with which taxed goods are substituted with alternatives. Global welfare rises with participation despite the distortions caused by trade restriction. Tariffs therefore seem to be a feasible means of increasing participation.

In the forth paper, I apply an extended version of the coalition model to issue linking of environmental agreements and technology oriented agreements. It turns out that linking the environmental agreement to cooperative research changes the incentive structure such that more actors sign the agreement. The type of technological knowledge that spills over makes a difference for the effectiveness of this type of issue linking: research cooperation focusing on productivity is unambiguously more effective than cooperation on mitigation technology in raising participation in the agreement, global welfare, and environmental quality. International technology standards are also shown to have a positive effect on coalition formation. While the existence of a separate standards agreement alone has very little impact on environmental cooperation, it significantly increases participation in a linked agreement on environmental and technological cooperation.

Overall, the studies reported in this thesis suggest that there is indeed potential that ITC may reduce the burden that mitigation requirements will put on the economy. And while there is no final conclusion on the magnitude of the impact of ITC due to the remaining model uncertainty, this thesis advances the understanding of these uncertainties and the underlying reasons for the variability in the results. To exploit a large potential of ITC, a clear carbon price signal is required. This thesis suggests that linking the negotiations on climate policy to trade sanctions or to research cooperations is a feasible way to create incentives that make a cooperative global climate policy more likely. More research is needed to determine the magnitude of the potential of issue linking, but its potential in general has been shown and different issue linking proposals have been characterized with respect to their advantages and disadvantages.