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Induced technological change in moderate and fragmented climate change mitigation regimes

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ABSTRACT

Climate change mitigation efforts are currently characterized by a lack of globally coordinated measures and predominantly moderate regional action. This paper compares the results from different Integrated Assessment Models to analyze the impact of such moderate climate change mitigation actions on electricity technology deployment and development, along with the impact of first movers taking stringent unilateral action-specifically, the EU and an EU-plus-China coalition. We find that a fragmented regime with moderate climate and technology targets produces significant emission reductions and changes in the adoption of electricity technologies towards low-carbon alternatives, promoting global technology change. The adoption of more stringent policies by the first movers implies a further transformation of their electricity sectors, but technology deployment outside the coalition is not significantly affected. Furthermore, the results in some models show (1) that first movers can benefit from early action by increased access to low-carbon energy carriers and (2) that delayed action implies the lock-in of carbon-intensive technologies leading to a slower transformation of the electricity sector later.

1. Introduction

Despite the global nature of climate change, the outcome of the recent Conferences of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen (2009), Cancun (2010), Durban (2011), Doha (2012) and Bonn (2013) suggests that the ideal of coordinated and stringent global policy action is not likely to be a near-term reality. Instead, domestic and regional action is taking place to reduce greenhouse gas emissions and deploy low-carbon technologies.

Several modeling studies have analyzed the effect of such differentiated climate change mitigation policy action. The 22nd Energy Modeling Forum (EMF-22) analyzed scenarios in which BRIC[1] countries delay their mitigation efforts to 2030 and other non-Annex 1 countries to 2050 [6,23,36]. They found that the delayed participation increases the global cost of mitigating climate change, especially with stringent mitigation objectives or when the non-participating regions have large mitigation potentials. Other studies, not part of the EMF-22, have found similar consequences from second-best climate change mitigation policies [20,12,5]. In particular, Keppo & Rao [20] highlight that non-coordinated global action can lead to delays in technological transitions. Bosetti et al. [5] discuss the benefits of early action and policy anticipation for developing countries and global deployment of low-carbon technologies. A more recent study from Jakob et al. [18] concludes that early participation of Annex I countries, China and India can significantly reduce global climate change mitigation costs and those regions can benefit from their

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early action. Furthermore, they found that the lock-in into carbon intensive energy infrastructure[2] increases global mitigation costs.

However, delayed action is just one of the possible future second-best climate change mitigation policies. Other prevalent policy positions include a wait-and-watch approach while undertaking only moderate action in the near and medium term (such as adopted by the US); or unilateral climate change mitigation action, as it is currently the case in the EU. The consequences of short-term moderate mitigation policies have been analyzed by Bosetti et al. [5] and analytically discussed by Olmstead et. al [31]. They conclude that the economic costs of long-term stringent climate change mitigation policies can be significantly reduced by undertaking immediate moderate action compared to not acting. Unilateral climate change mitigation policies have also been analyzed in the EMF-29 with a particular emphasis on border carbon adjustment [2] and in other single model studies (e.g. [7]).

This paper contributes to the literature by means of an analysis of the effects on technology adoption of a moderate (weak) short- and long-term climate change mitigation policy. Furthermore, since the 2011 Durban Action Platform aims to attain a global agreement not later than 2015 and opens the door to the establishment of coalitions, we also analyze the potential role of unilateral stringent actions in the EU alone or in the EU and China together, and with alternative long-term policies in the rest of the world. A stringent unilateral policy is expected to provide an additional carbon price signal that promotes, in the coalition, the adoption of low-carbon technologies and creates incentives for technology innovation [7,8]. However, what happens outside the coalition is not clear. On the one hand, carbon leakage effects[3] could lead to lower fossil fuel prices in the non-participating countries, encouraging increased use of fossil-based technologies. On the other hand, low-carbon technologies, developed due to the mitigation policy in the coalition, can diffuse to other regions through technology transfer instruments such as the Clean Development Mechanism [11,32], or international trade and foreign direct investment activity of firms [19,7]. In this paper, we focus especially on the induced technological change in the electricity sector inside and outside the coalition. This technological change is reflected in the adoption of low-carbon electricity technologies, which is directly linked to the achievement of climate change mitigation objectives: in particular, the deployment of renewable-based technologies, nuclear power plants and carbon capture and storage (CCS) options, as described in recent analysis of mitigation scenarios, such as in the IEA Energy Technology Perspectives [15] and the IPCC's Fourth Assessment Report [34].

Besides the adoption of low-carbon technologies, both moderate and unilateral stringent climate change mitigation policies can create incentives for technology innovation [8]. Technology innovation refers to technical and economical improvements of individual technologies. This process of technological change arises from three interacting factors: experience in the production, deployment and use of the technology; private and public research and development (R&D); and spillovers between sectors, companies, industries or countries [13,9]. The first refers to improvements due to the so-called "learning by doing". The second factor is related to R&D done by firms, governments, or other entities that lead to technology improvement [13]. Finally, technology learning spillovers refer to the transfer of knowledge from a firm, sector or country undertaking innovative activities to another. Technology change, including both technology adoption and innovation due to R&D, can be analyzed ex-post and ex-ante [8]. The first type of analysis uses econometric methods and surveys (e.g. on patents) to determine the impact of existing policies on technology development. The second type analyzes the effect of future policies using models that include a macroeconomic representation of technology change. In these cases, technology change is modeled as the evolution of the investment cost of the technologies, determined either exogenously or endogenously [9]. Both endogenous and exogenous approaches have been criticized. The exogenous approach, used for instance in the IPCC's Special Report on Emission Scenarios [30], does not link climate change mitigation or technology policy with technological change. While the endogenous approach does, it has been criticized due to the fact that this endogenous technological change is in many cases modeled just for the energy sector and using simplified one- or two-factor learning curves [9]. Learning curves are used to describe the behavior of the investment cost of a technology with respect to cumulative production (first factor) and/or investment on research and development (second factor) [22]. This approach is often criticized due to the uncertainty in the learning coefficients, failure to represent other aspects of technology learning, such as spillovers, and for the difficult interpretation of the results. However, given the importance of including a representation of induced technology change in the analysis of long-term mitigation policies, learning curves are still a widely used tool [9]. See for example, Bosetti et al. [6] or Tavoni et al. [35]. In this paper, we analyze the effect of a moderate climate change mitigation policy on endogenous global technology learning and the additional consequences from unilateral action. Since a moderate and differentiated climate change mitigation policy can be considered as reflecting the current global state, our analysis contributes to understand technology innovation possibilities arising from uncoordinated global action.

In the first part of the paper we analyze how a moderate (weak) climate change mitigation regime affects global electricity technology adoption and innovation. In the second part, we analyze the effect on technology deployment and development of a unilateral climate action from the EU and an EU-China coalition, beyond the moderate global climate change mitigation policy. For these analyses we use the results of scenario quantifications from different models included in the AMPERE project [25]; these include primarily integrated assessment models and bottom-up energy system models as described in

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[2] The term technology "lock-in" refers to incumbent technologies preventing the adoption of potentially superior alternatives due to factors such as market characteristics, institutional and regulatory aspects, returns to scale (so that the best/cheapest technology is not chosen), and expectation of consumers, among others [1,14]. However, in the IAMs compared in this study "technology lock-in" refers to energy infrastructure being employed until the end of its lifetime without the possibility of early retirement.

[3] The IPCC's Fourth Assessment Report defines carbon leakage as "the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries" [17].

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